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# EDITORIAL.

## ITEMS AND NOVELTIES.

**The Passivity of Iron.**—To produce in a certain manner the somewhat capricious phenomena of passivity, says M. de Regnon, I use iron wires or rods of fencing-foil, the surface of which is protected, for a certain length, by a glass tube or a layer of mastic. The free extremity, with a length of two to three centimeters, is plunged entirely in the acid.

I. An electric current *entering* by the iron into nitric acid, renders the iron passive while the current lasts; and after rupture of the current the iron remains passive. A current *leaving* by the iron destroys the passivity, and this change of state may be reproduced indefinitely. Iron acting as the positive electrode in a mixture of sulphuric acid and water, liberates oxygen, is weakly attacked, and becomes passive for nitric acid. A reversal of the current's direction destroys the passivity.

II. One may *stop* the attack of iron by nitric acid, by touching or (better) rubbing it in the nitric acid with a body that is a good conductor and not attacked by the acid, such as platinum or conducting charcoal. This action of charcoal explains why steel and cast iron become passive of themselves. The experiment succeeds better the larger the surface of contact, and the larger the total surface of the

body which is not attacked. Further, the more concentrated the acid, the more easily is the passivity obtained.

III. The contact of a metal attacked by acid destroys, it is known, the passivity. If, then, we put in contact a passive iron wire and an active wire, the final effect will be either the attack or the passivity of both wires. We may unite in a single experiment these two contrary results; immerse the extremity of a piece of foil (the whole surface of which is exposed) in nitric acid to a length of two or three centimeters. After a short attack, the part immersed becomes passive, and is covered with a dark deposit containing carbon. This done, if we suddenly immerse the foil to a fresh length of three or four centimeters the attack commences from above, is propagated to the lower part, and, when the passivity is anew produced, we find the whole of the immersed length charged with black deposit. In this first case the active portion destroys the passivity of the extremity. If, on the other hand, we immerse the foil slowly in the acid, it will remain passive without the part newly immersed undergoing the least attack, as is evident from its clear and bright look. Here the passive extremity communicates its state to the other portion.

IV. We may bathe the end of a wire in water, without destroying the passivity, provided care is taken not to immerse the wire in the water beyond the protective mastic. We may even scrape the wire, in the water, with another passive wire, or with the end of a clean tube of glass, without its state being changed, and this experiment quite destroys the explanation of passivity by formation of an insoluble deposit.

V. I have tried the action of other liquids after having each time bathed the passive iron in pure water, and I have verified the proposition (already known): Oxidating substances are without action on passive iron. Deoxidating substances destroy the passivity.

VI. We may perceive that the actions of contact are reducible to electric actions, by means of the following experiments:

1. Connect together a wire of iron and a wire of platinum terminating in a spiral. Plunge the free end of the iron in the acid, and when the attack has commenced, introduce the spiral of platinum into the same glass or into another glass containing acid, and put in communication with the first by a bridge of platinum. In an instant the iron becomes passive. The same experiment succeeds on connecting iron with conducting charcoal instead of platinum.

2. On the other hand, connect an iron and a copper wire. Plunge

in the acid the free end of the iron, and render it passive by rubbing with platinum or with passive steel. This done, introduce the end of the copper wire into the same glass, or into another glass as above, and immediately the iron is attacked.

3. Plunge into a glass filled with acid, or into two glasses connected by a bridge of platinum, the two extremities of two wires of iron connected exteriorly by a conductor. If we then rub in the liquid one wire only with platinum, both become passive; if we touch one wire with copper, both become active. These experiments are more delicate than the preceding, owing to the electric resistance of the liquid.

VII. The passivity may be destroyed in another manner, which shows the *role* of electricity. Connect the wire of a galvanometer, on one hand, with a spiral of platinum or copper, which has been plunged in a conducting liquid that does not destroy the passivity, *e.g.*, a solution of nitrate of potash, and, on the other hand, with a wire of iron protected by mastic as explained. Then close the circuit by introducing the iron into the nitrate; the needle indicates an immediate and permanent current going from the galvanometer to the iron. We obtain the same result (which is easy to foresee), if, after rendering the iron passive, and washing it well with water, we immerse it an instant in a liquid which destroys the passivity: *e.g.*, in a solution of marine salt. But if we close the circuit after having washed the passive iron in water, or in a liquid *without* action on the passivity, we perceive a slight movement of recoil in the needle, indicating a first current of very short duration, going from the iron to the platinum by the galvanometer; then the needle is forced in the contrary direction, and indicates a permanent current from the platinum to the iron. But one finds that, immediately this action is produced, the iron has become active again.

VIII. All these experiments seem to me to legitimize the following conclusions:—1. Most of the causes which produce passivity in iron may be reduced to a voltaic force carrying the oxygen to the iron and polarising it on the surface of this metal. 2. Most of the causes which destroy the passivity of iron may be reduced, either to a voltaic force of the contrary direction, or to a current due to polarisation of the oxygen, and by which it is exhausted; or, lastly, to an absorption of the polarised gas by a body that has avidity for oxygen. I hope shortly to show that these phenomena of passivity are more general than is supposed.

IX. We can now explain two experimental precautions that were insisted on:—1. It is necessary to protect, with an impermeable layer, the portion of wire which is not plunged in the acid, otherwise the acid vapors bring this portion into a state which is opposed to the passivity of the immersed part. 2. When we bathe the passive extremity in water, the metal should not be immersed above the mastic, otherwise the passivity is immediately destroyed, for a circuit is closed by which the polarization is exhausted.

Most of the above experiments were made with nitric acid, marking 35 deg. B.—*Iron.*

**Carbonic Acid Gas Engines.**—The following account of the new Carboleum engine of Dr. Beins, which has recently created some excitement as a new motor, we take from the editorial columns of the *Engineer*. We value it especially because of the criticisms with which it is accompanied, which we regard as eminently just:

Faraday was, we believe, the first to liquefy a gas. He used small glass tubes, and an account of his experiments may be found in most treatises on chemistry. The subject was earnestly taken up by Thilorier, who devoted his attention principally to carbonic acid, which he succeeded in solidifying in considerable quantities. The apparatus he used was imperfect and caused some serious accidents. Natterer of Vienna produced a better apparatus, and this was improved upon by Bianchi, who produced a really workable gas-liquefying machine, by the aid of which carbonic acid in the liquid state can be produced by the pound. To make it, two things are necessary—a pressure of about 40 atmospheres, or 600 lbs. on the square inch, and a ready means of abstracting the heat developed by the work of compression. This last is usually supplied by a freezing mixture. The use of solid or liquid carbonic acid as a motor has often been proposed. But those who have mastered the laws of the conservation of energy will understand in a moment that carbonic acid or any other gas which admits of liquefaction, can not originate power. It can become a storehouse of power and nothing more. In a word, a pound of liquid carbonic acid will, in the course of its reconversion into gas, give out just the power expended in compressing it and no more. But a large proportion of that power was converted into heat, and this heat must be restored to the liquid before it can become gas. But the heat expended in liquefying carbonic acid is just the same, according to ordinarily received laws, as would be expended in com-

pressing air to the same extent. That is to say, it will be raised in temperature one degree Fahrenheit if it is reduced in volume by 1-490th. If we compress carbonic acid gas to 32 atmospheres, or 480 lbs. on the square inch, the temperature will be raised to about 2450 deg., while the temperature due to 64 atmospheres would be 2940 deg. The specific heat of carbonic acid is ·217. A cubic foot of the gas at 32 deg. weighs 0·12259 lb. One pound under these conditions occupies 8·157 cubic feet. In rising to the temperature of 212 deg. it will expand ·365, and to raise one pound of carbonic acid one degree in temperature, 167 foot-pounds of work must be done. This last is really the important factor when we come to deal with carbonic acid as a motive power, and for the moment all else may be neglected. We have seen that by compressing carbonic acid gas into 1-32 of its bulk at atmospheric pressure the temperature will be raised, in round numbers, to 2450 deg.; but each degree by which we raise 1 lb. of the gas represents 167 foot-pounds; consequently the whole work that will be done in compressing 1 lb. of carbonic acid gas 32 times will be $167 \times 2450 = 409{,}150$ foot-pounds, which, if exerted in one minute, would represent nearly $12\frac{1}{2}$ horse-power. Put in another way, the consumption of compressed carbonic acid gas would be about 5 lb. per horse power per hour, provided we could realize the whole of the force stored up in it. But it must be borne in mind that, during the work of compression, the whole of the heat squeezed out of the gas, if we may use the term, must be wasted; and before the gas can resume its original volume—do work in fact—this heat must be restored, and this being the case, it would be just as practicable to use air as carbonic acid gas. Neither possesses any advantage over the other worth consideration; unless indeed it can be shown that some method exists by which we can obtain carbonic acid gas under high pressure by the aid of fuel which would otherwise be wasted.

Bearing these facts in mind, we shall be in a position to understand a proposition just put before the world by Dr. H. Beins of Groningen. This proposition has reached us in the form of a circular, but indifferently translated into English from the Dutch. Dr. Beins' idea is, so far as we comprehend it, to heat bicarbonate of soda or potash to a high temperature under pressure, and thus to obtain carbonic acid gas, of high tension, or even in its liquid state. The definite statement is that "at a temperature of 300 deg. to 400 deg. C. liquid carbonic acid can be distilled out of these salts with a tension of from 50 to 60 atmospheres." We are not aware whether such a process has ever

been tried before by chemists, and we shall not dispute Dr. Beins claim to be the first discoverer of the process. He proposes to utilize it in the production of motive power, and we shall now allow him to explain himself.

"One litre of *Carboleum*—liquid carbonic acid—of 50 deg. C. and a tension of 50 atmospheres weighs approximately 0·8 kilogram, and can produce 400 liters of carbonic acid gas of the ordinary atmospherical tension. Suppose now these 400 liters compressed to 50 atm. The work required for that compression is represented in every case (however much may be the anomaly with regard to Boyle's law) by a mathematical figure of the same area as the hyperbolical plane, that represents the power of compressing an equal volume of air to 50 atm. and this amounts to about 17,000 kilogrammeters. Per horse-power and per hour (270,000 kgrmmtr.) about 16 liters carboleum of 50 atm. and 15 deg. C. is thus required. Here and in the following I take for greater simplicity even numbers. Only when a carboleum engine works with great intermissions can the heat of vaporation required be taken from the sides of the reservoir without artificial heating. In the majority of cases, however, the carboleum must be evaporated by the artificial heating of small quantities at a time. The heat required per horse-power hourly (270,000 kgmmtr.) amounts at least to 640 calories (0·1 kilogr. of coal.) But now the objection may be made the quantity of carboleum required for an engine of greater dimensions and continuously working is too considerable, and therefore the reservoirs must be made too heavy. And for this reason carboleum would not be applicable otherwise than for small engines working with intermissions. The fact is that greater carboleum engines must work with regeneration. They must have a store of sodium bicarbonate and of carboleum, so that the decomposed bicarbonate is regenerated again by the carbonic acid that has worked in the engine. Such an engine transforms very advantageously the heat (furnished by the fire for decomposing the continually regenerated bicarbonate) in mechanical work. Supposing the gas working with a temperature of 100 C. the 16 liters of carboleum required hourly per horse-power are reduced to 10 liters. Such an engine requires about 0·3 kgrm. of coal per horse-power hourly, whilst the best steam engine requires 1.2 to 0·9 kgr."

The preceding calculations look very well on paper, but it is obvious that Dr. Beins believes that he can get something in the way of power for nothing in the way of coal. We have shown that the only

result to be had from the use of liquid carbonic acid is a result purely equivalent to the power expended in compressing it. The work of regeneration, as the inventor calls it, depends on the application of heat; and the work done will be just the same whether the gas is compressed in the process of manufacture from bicarbonate of soda or potash, or by hand, or by a steam engine. The carbonic acid is as powerless in the whole cycle as the water in a boiler or the piston in an engine. It can originate nothing, and it does not require much experience to become aware of the fact that carbonic acid is an exceedingly inconvenient medium to deal with in the development of power from fuel; and to fuel Dr. Beins must ultimately resort. There may, perhaps, be situations in which carbonic acid gas could be made useful for driving small engines; but they must be few and far between. It is not impossible, however, that the proposed system of obtaining carbonic acid gas under high pressure may prove of considerable commercial importance, as, for example, in the aerated water trade.

**The Stevens Institute Mechanical Laboratory.**—The following is the text of the letter from the Trustees of the Stevens Institute of Technology at Hoboken to Professor R. H. Thurston, establishing the Mechanical Laboratory which he had suggested. The idea is a most excellent one and is as important as it is novel:

SIR:—The Trustees, after a more thorough consideration of your letter of January 30th, referring to the necessity of a laboratory devoted to technical research, and especially designed to meet the necessities of the industrial interests of the country, have decided to assume the initiative, and to endeavor to provide the nucleus of such an institution as that proposed in your letter just referred to. You are, therefore, authorized and requested to organize a Mechanical Laboratory, as an adjunct to your department, and to assume the direction of its affairs.

You will take charge of such contributions as may be made by those interested in the creation of such an establishment, whether of apparatus, of machinery, or of capital, and account for them to the Trustees. In accepting such contributions, you will submit to the Trustees the proposed conditions of acceptance before completing any agreement with the contributors. You will, in the expenditure of funds, in the erection of buildings, the purchase and establishment of apparatus and machines, and in the employment of subordinates, use every precaution to secure the greatest economy, and a full equivalent

for funds so used. You will establish all necessary regulations for the successful operation of the new department, and will provide such a schedule of charges for work done for private parties as shall cover actual expenses and give a margin of profit, amounting to not less than twenty per cent. of such expenses, which profit shall be charged to a capital account for the purpose of securing a gradual increase of the stock of apparatus, and the accumulation of a fund which may ultimately be used in the erection of buildings, and in securing enlarged facilities for special researches. In making regulations for the guidance of those having occasion to avail themselves of the facilities which it is proposed to provide for the examination of materials and for research, you are desired to make provision, where possible, for a fair return upon their investments to those who may aid in the establishment of the Laboratory.

You will make a report to the Trustees in January of each year, in which you will state the amount, and the character of work done during the previous year, the condition of the department, its growth, and its wants. You will be expected to render an account of receipts and expenditures semi-annually, January 1st and July 1st; and in the statement, which shall accompany the annual report, you will give an account of stock, and a statement in full of the value of all property held on Laboratory account.

The Trustees of the Stevens Institute will transfer to the Director of the Mechanical Laboratory the following property, to be held and used for the benefit of said Laboratory:

1 Steam Engine of 4 horse-power; 1 Engine Lathe of 15 inch swing; 1 Speed Lathe; 1 Power Planing Machine, 5 feet bed; 1 Small Hand Planing Machine; 1 Universal Milling Machine; 1 Upright Drill; 1 Emery Grinder and Wheels; 1 Set of Tapsand-Dies; 1 Set Reamers; 1 Set Whitworth's Gauges; 1 Lot Miscellaneous Tools, as per inventory to be submitted; 1 Testing Machine, with autographic registry, to break iron and steel $\frac{5}{8}$ inch diameter; 1 Emerson Dynamometer; 1 Salleron Dynamometer; 1 Woltmann Mill, for determining velocity of streams; 1 Baumgarten Mill, for determining velocity of streams; 1 Wheel, with Dial for determining velocity of water; 1 Pilot Tube, with Dial for determining velocity of water; 1 Anemometer; 2 Richards Steam Engine Indicators; 1 MacNaught Steam Engine Indicator; 2 Spring Balances, British Measure; 1 Spring Balance, French Measure; 1 Blacksmith Forge.

To the above list there will be appended some other apparatus as yet unselected, the whole having an estimated value of $5000.

The boilers of the Institute will be allowed to furnish steam to drive the engines and tools.

The Trustees will assume charge of permanent funds, and will endeavor to invest them properly. They will decide when it may be advisable to expend all or any portion thereof for the purpose of enlarging the field of usefulness of the institution for the benefit of which they may have accumulated.

You are authorized to make use of such available space within the building of the Institute as shall be necessary for the accommodation of the proposed Institute, and to call upon the employees for such assistance as may be needed, whenever such aid may be rendered without interfering with their regular work, or their duties to the officers of the Institute. It is presumed that such assistance will meet all requirements for several months at least.

Whenever it shall occur that a total subscription of sufficient amount to erect buildings shall have been received, the Trustees will further appropriate to the use of the proposed Mechanical Laboratory a strip of land adjacent to the Stevens Institute of Technology, not exceeding two hundred feet in length and fifty feet in breadth, valued, at present prices, at not above twenty thousand dollars, on which such buildings may be erected.

The total appropriation thus made is to be credited to the Institute as a shareholder, for its amount, $25,000. The Trustees will also hold themselves in readiness to share the management of the Laboratory with a Board of Trustees, of which the President of the Stevens Institute shall be *ex-officio* President, and on which Board contributors shall have representation in proportion to the aid given; this transfer to take place whenever the majority of stock representing subscriptions shall vote it advisable.

**A New Motor.**—According to the laws of the mechanical theory of heat, any difference of temperature may be employed for the production of mechanical work. If a cold body then, be situated in air that is hotter, the passage of heat to it should be capable of giving mechanical work. The solution of this problem, M. Enrico Bernardi, an Italian physicist, has recently sought to realize in the following way: (*Il Nuovo Cimenti*, 2, xi. 27.)

Two similar glass balls are connected together by a thin glass tube,

the ends of the tube passing into the balls, being bent at a right angle. One ball contains a small tube, by which ether can be poured into the apparatus; the ether is brought to boiling, and when all the air has been expelled, this small tube is closed by fusing. The quantity of ether enclosed in the system should be such as to fill about three fourths of one ball. At the middle of the connecting tube is fixed a piece through which passes a metallic axis, round which the system can turn. When the ether is equally divided between the two balls, the apparatus is in unstable equilibrium. The bearings for the axes are supported on the cover of a rectangular case, and in this cover is a slit through which the turning system passes. The case is filled with water into which the balls dip alternately on their being turned round the axis. Each ball is covered with a very fine veil. It is easy to see that this apparatus will take a sea-saw motion.

"In this apparatus," says M. Bernardi, "there is a continuous flow of heat from the surrounding parts to the case, as the water in this is kept at a lower temperature through the balls, which, cooled by evaporation, periodically sink into it. If we were to draw a comparison between my apparatus and a steam-engine, we should assign to the surroundings the *role* of the fire, to the case that of the furnace, to the under ball that of the steam boiler, to the upper that of the condenser. In this way it would be readily understood, that the work developed in the apparatus is a transformation of a portion of the heat which continuously passes from the surroundings to the case."

It would be rather troublesome to utilize this thermo-motor see-saw mechanically, and M. Bernardi has, therefore, preferred to alter the apparatus in the following way: The two balls of the above described system are connected by a tube, the ends of which are bent round (at right angles) to opposite sides. Three such systems are formed into a sort of wheel, the middle points of the six balls and the tubes being in one plane. This wheel is supported at its axis, on the cover of a rectangular case in such a way that, in its rotation, it is always half within the case and half in the air. The balls are covered, as before, and so much water is poured into the case, that, in turning the wheel, one ball is always immersed. By giving the wheel a turn it can be set in continuous rotation, and, with a suitable arrangement of pulleys, it can be made to raise a weight, or do other work.

Such a thermo-motor wheel has, for two months, been working a clock, in M. Bernardi's laboratory. The balls have a diameter of two centimeters (·8 inch;) the distance of the middle points of two oppo-

site balls is eight centimeters (3· 2 inches,) and the quantity of ether in each system fills three-fourths of a ball. The clock maintained in motion by this wheel consumes, in 24 hours, 0.035 kilogrammeter. The water level is kept constant by a special arrangement.

In both see-saw and wheel, the dissolved salts of the constantly evaporating water must gradually be concentrated. The less soluble appear crystallized on the surface of the balls and of the case; the soluble salts delay the evaporation, and so lessen the quantity of heat withdrawn from the balls, and therewith the work furnished. The evil is remedied if distilled water, rain-water, or snow-water, is used; otherwise the apparatus must occasionally be cleansed by means of dilute muriatic acid or by nitric acid. Using the ordinary drinking water of Vicenza, M. Bernardi has had his see-saw working for three months without its becoming necessary to renew the water or to clean the balls.

The author has tried to calculate the quantity of heat which is removed by this apparatus from the surroundings. To this end, he so arranged a see-saw, that each time when the balls passed through the opening in the cover, this opening closed, and the water was thus always in a closed space. This space was further protected against variation of temperature by means of a water-jacket. As the water by this arrangement, was guarded against all loss of heat, the work of motion furnished the data from which could be estimated the heat consumed. In a window not exposed to the sun, observations were made from the middle of February, to the middle of March, and there was an average of sixty see-saw motions in twenty-four hours. Calculating, from the weight of the ether, and the change in the center of gravity at each turn, the amount of work done in twenty-four hours, this was found to be equal to 0·018 kilogrammeter, or about half the work consumed in the same time by the clock.

As to the "moments" which affect the amount of work furnished by these apparatuses, they depend, first of all, on the quantity of heat which in a unit of time is removed through evaporation of the water of the upper ball, and so on the temperature and moisture of the air and of the moistened surface of the balls. Further, the thickness of the balls is of influence and under conditions otherwise, the number of units of heat which the contents of the ball lose in a unit of time is less, the thicker the glass. The rapidity with which the see-saw movements follow one another, is, lastly, influenced by the somewhat rapid variation of the air; the movements become more

frequent if the temperature of the surroundings falls, and more seldom if it rises; for the water in the case cannot follow so quickly the variations of temperature.—*English Mechanic.*

**A New Joint for Boxes.**—A method for making joints to unite the sides of boxes and other matters, has been recently patented in England, by Mr. W. M. Beaufort. The two pieces of wood to be fastened together are first mitred in the usual manner, and a hole is then drilled vertically in each piece, from the bottom upwards at a short distance from the mitred edge. A channel or groove is then cut, by a saw or otherwise, from the mitred edge to the drilled hole. This channel is of a less width than the diameter of the hole, and may be cut either parallel to the sides of the piece of wood, or at right angles to the mitre, so that when the two pieces of wood are put together, a continuous channel shall be formed between the two holes. The two pieces are then held tightly together and a key is formed by running metal such as lead, or fusible metal into the channel; by this means the key is cast in the place which it is to occupy. The key may also be made separately, of solid metal, and driven home into the channel.

**Improved Tuyere for Forges.**—We find in the English journals, the following notice of a paper read by Mr. W. Smyth, before the British Association, which described a very simple but important improvement in smith's forges, by which the forge is much more fully under the control of the workman, and by which the life of the tuyere is greatly prolonged, the work of heating the metal more uniformly and uninterruptedly carried on and a great economy of fuel effected. A cast-iron trunk or box is placed horizontally from the back and front of the forge. The front end is closed by means of a slide or door. The back end has a hollow tower which rises above to a suitable height, and upon which is fitted a cast-iron tuyere block, with by preference, two long slot-holes for the blast. Within the trunk is a long lever working in an axle or spindle, which at its longer end has two punches which rise vertically, and are from time to time projected through the slots to displace the slag and keep the tuyere openings clear. This the workman does, by moving a lever upon the outer end of the spindle or fulcrum of the levers. The iron trunk or box becomes heated by the surrounding fuel, and utilizes the heat, which would otherwise be wasted; thus effecting a considerable economy of fuel by heating the air of the blast.

# Editorial Correspondence.

[The following letter from Col. G. Howard Ellers, C. E., upon the use of Nitro-glycerin in blasting, was written at the request of a gentleman of this city, for a friend of his at the West, who desired to use this explosive practically. Deeming the facts it contains of general interest to our readers, we have obtained a copy of the letter for publication.—ED.]

## On the Use of Nitro-glycerin in Rock and Earth Excavations.

My Dear Sir: I have the honor to acknowledge the receipt of your communication of the 21st inst., and in response thereto, beg leave to say, that in such material as you describe, cemented or indurated earth, hard pan, etc., etc., the use of nitro-glycerin will scarcely be found as economical as powder. In the older rocks, granite, gneiss, limestone, quartz, etc., nitro-glycerin will do the work at fully half the cost as compared with the best blasting powder. There are many different qualities of nitro-glycerin, varying fully fifty per cent. in power and purity, and, while the pure article is *perfectly safe*, and does not readily change in store or magazine, the spontaneous explosion of an impure article is merely a question of time and temperature. There are many circumstances controlling the use of this most valuable explosive agent, a proper knowledge of which will often save both time and money;—for instance—a diffusion of *ten per cent. of water* will *diminish* its blasting power thirty per cent. while an increased power of fully thirty per cent. is obtained by charging directly in the drill hole *over what is evolved*, when the metallic shell of the cartridge and a stratum of air and water are interposed between the gases of explosion and the rock acted upon. I am unable to say how much *loose earth* a given charge will move or throw down, never having used it in anything but rock and large erratic boulders, and I know of no one from whom such information can be obtained. As I have already said, the maximum useful effect of nitro-glycerin, as a blasting agent, is reached in the older and harder rocks; in loose material it is not so effective. The following are substantially Mr. Mowbray's instructions for use and handling, and he probably knows more about the subject than any man in America:

1. Handle with the greatest care, avoiding every possible jar or concussion, and be very careful, if any is spilled outside the can, *to avoid striking it with or against any hard substance.*

2. When in a solid state, thaw out by placing the cans in a vessel of *warm water, never warmer than the wrist can bear*, first pouring some of the warm water *from the vessel into the can*, and *always removing*

*the can or cans* before adding more *warm water* to that in the vessel in which the cans are placed.

3. When filling cartridges hold them carefully over a tray, about $2' \times 3'$, the bottom of which must be thoroughly *covered* with "Plaster of Paris," which latter must be replaced as rapidly as lightly saturated with the nitro-glycerin. (Memo., plaster of Paris saturated with Nitro-glycerin *does not readily* explode.)

4. If necessary to store nitro-glycerin in a liquid state for any length of time, *insert the cork loosely*, and pour a pint of *cold water* in each can, which water must be frequently and carefully poured off and *replaced with fresh cold water* in *warm weather*, always taking care to retain the bladder under the cork. If ice can be procured, however, it is both safer and more desirable to congeal the nitro-glycerin and keep it in the solid state.

5. Use gutta percha funnels for filling water holes—never tamp the drill holes, it is totally unnecessary and is pretty sure to kill the individual who does it.

6. Never use hot irons to warm the water, or for soldering the cans, both are sure to cause explosions.

7. Never sledge or drill in a hole or seam where nitro-glycerin has been spilled, without first firing an exploder to clean the place out.

8. Never pour nitro-glycerin into a hole, unless perfectly sure that the hole is sound and will hold water; if otherwise, always use a cartridge.

9. To obtain the best results, use drill holes always 6 feet in depth, or over, fire with powerful exploders and well insulated wire, by electric battery and with simultaneous explosion.

10. After a blast, look carefully for any unexploded cartridges that may be laying around loose.

11. Allow none but the most careful, competent, and sober persons to handle or have charge of nitro-glycerin, and enforce a rigid obedience to orders and compel the adoption of every precaution to prevent accidents or explosions.

12. Never use empty cans for other purposes, transport them to a safe place, and then destroy them by fire, or with a fuse and exploder.

13. Carefully examine the cans from time to time, and notice if any pin holes have been eaten through at the level of the nitro-glycerin therein. Should the presence of such holes be detected, procure new cans or stone jars, and place the contents of the unsound cans therein, never trusting your hold on the upper portion of the unsound cans, lest it break loose and trouble ensue.

14. When congealed, nitro-glycerin is absolutely safe; if possible, therefore, it should always be stored surrounded with ice, since explosion is impossible when in a solid state.

The present price is about $1.65 per pound delivered—the electric exploders are about 30c. for 10 feet wires, and 25c. for 8 feet wires. Some changes in these figures may be made about the first of next

month. If you have any important work on hand requiring the use of nitro-glycerin, or of a difficult or dangerous character, I shall be most happy to undertake it at any time.

Trusting the foregoing may meet your requirements, I am, etc., very cordially yours,

(*Signed,*) G. HOWARD ELLERS,
Chief Engineer.

Troy & West Troy Bridge Co.,
Chief Engineer's Office, Troy, N. Y., May 25, 1874.

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**Prompt Passenger and Freight Transportation in New York.**—The American Society of Civil Engineers has taken in hand the matter of a cheap and ready method for transporting passengers and freight in New York city. Its Committee desires communications upon the subject, as will be seen by the annexed circular, which has been sent to us for publication:

"At the regular meeting held September 3d, 1874, it was—

"RESOLVED, that a Committee of five members of this Society be appointed by the President, to investigate the necessary conditions of success, and to recommend plans for—First: The best means of rapid transit for passengers, and Second: The best and cheapest methods of delivering, storing and distributing goods and freight, in and about the city of New York; with instructions to examine plans, and to receive suggestions such as parties interested in the matter may choose to offer, and to report on or before the first day of December, 1874.

Messrs. O. Chanute, M. N. Forney, Isaac C. Buckhout, Charles K. Graham and Francis Collingwood were appointed such Committee.

You will confer a favor upon the Committee and the Society by furnishing whatever contribution or suggestions you may deem of value on the above subjects, or by calling attention to the sources of such information. Due credit will be given for all aid rendered to the Committee.

In referring to plans proposed to accomplish these objects, it is particularly desired to ascertain accurately—First: The route and location proposed, and the reasons therefor. Second: The character of structure proposed in various parts of the city. Third: A close estimate of the cost in detail.

It is greatly preferred that all communications shall be in writing. Please address,

G. LEVERICH, Secretary American Society of Civil Engineers,
63 William street, New York."

# Franklin Institute.

HALL OF THE INSTITUTE, June 22d, 1874.

The meeting was called to order at the usual hour and Mr. Charles S. Close was on motion called to the chair. He announced that the purpose of the meeting was to exhibit and discuss the operation of Charles Henry Hall's Patent Pulsometer, and Prunty's Patent Automatic Relief valve and cut-off for fire-hose.

The meeting was conversational in its character. Messrs. G. W. Storer, S. L. Wiegand, Charles Bullock, Thomas J. Lovegrove and Professor R. E. Rogers participated in the discussion on the Pulsometer and elicited the following facts:

That the Pulsometer is economical for raising water for lifts not exceeding 26 feet; but in forcing water by pressure it derived no benefit from the expansion of the steam. The temperature of the water raised was increased about three degrees Fahrenheit.

Mr. Robert Grimshaw exhibited Prunty's Relief valve and cut-off applying them to tubes connected with the pulsometer which was forcing water under a pressure of steam of 80 pounds per square inch.

In every instance the closing of the cut-off at the jet muzzle instantly opened the relief valve without any appreciable concussion, although more than 50 feet of fluid column was arrested between the jet tube and relief valve.

Mr. S. L. Wiegand announced that full descriptions of both inventions would appear in reports from the Committee of Science and the Arts, and that stereopticon illustrations of them were incourse of preparation.

On motion the meeting was adjourned.

(Signed) W. H. WAHL, *Secretary.*

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*Erratum.*—In the August number of this Journal, in the table of drop tests for phosphor-bronze on page 143, in the third line near the end, the words "3 foot blows" should read "8 foot blows."

# Civil and Mechanical Engineering.

## THE STEVENS IRON-CLAD BATTERY.

[The famous "Stevens' Battery,"—the earliest of all iron-clads, so far as its earlier design and the actual commencement of its construction antedate all other structures of its class, and the most modern in plan and the fastest and most formidable of existing war vessels as now reconstructed by General McClellan,—is to be sold without reserve, and to the highest bidder on the second day of November.

The advertisement of the Consulting Engineer to the Commission appointed to effect the sale for the State of New Jersey and for the estate of Edwin A. Stevens, by whom the craft was bequeathed to the State, has made known the principal dimensions of the great steamer to the readers of all engineering, mechanical and naval periodicals, both in this country and in Europe.

The historical interests attaching to this powerful war-steamer, as well as the exceptionally formidable character of the iron-clad itself have induced us to procure for our readers the following abstract of the report of Professor Thurston, the Consulting Engineer. This report has been published in full and in beautiful shape, for the Commission, by Van Nostrand.

The Commission consists of Governor Joel Parker, Vice Chancellor Amzi Dodd, the Hon. W. W. Shippen, and the Rev. S. B. Dod. —Ed.]

### DESCRIPTION OF HULL AND MACHINERY.

#### HULL—GENERAL DIMENSIONS.

| | |
|---|---|
| Length over all | 401 feet. |
| " between perpendiculars | 390 " |
| Breadth | 45 " |
| " over armor | 54 " |
| Depth to main deck | 24½ " |
| Draught, maximum, fore and aft | 22 " |
| Displacement at 22 feet draught | 6006·02 tons |
| Area of immersed midship section | 890·26 square feet |
| Ratio of immersed midship section to circumscribing parallelogram | 0·867 |
| Ratio of displacement to circumscribing parallelopiped | 0·544 |

The general appearance of the vessel, if completed as here proposed, will be that of a "Monitor" iron-clad, such as is illustrated in the accompanying engraving.

The form of the hull is shown in Plate I, Figs. 1, 2 and 4, on which are exhibited the lines as obtained by actual measurement of the completed hull. Figure 3 represents a cross section through the engine compartment.

The proportion of length to breadth—8·666 to 1—is that now usually observed in sea-going high-powered steamers, and is somewhat less than in those which represent the extreme limit yet attained. The lines are fair and fine, giving a sharp bow and the fine run which is essential to the efficient working of screw propellers. The proportions of the midship section, which has a breadth equal, very nearly, to double the intended draught, are such as are best calculated to make the vessel easy in a sea-way.

On Plate I, Figure 5, is shown the Curve of Displacement, as estimated from measurements taken by the Engineer in charge during construction, and as checked by the Consulting Engineer. The displacement per foot of draught at the intended load line is 424·19 tons, or 35·35 tons per inch. Removing the armor shelf, for the purpose of converting the ship to other use, the displacement at 22 feet draught would become 5,658 tons, and the additional displacement per foot of draught, would become 335 tons, or 27·9 tons per inch. In this case, it would become necessary to build up the ship one deck, and it might be advisable to build up two decks. If considered proper, an additional displacement could be thus secured, giving a total of 6,329 tons at 24 feet draught, which draught can be carried over the bar at the entrance to the harbor of New York, and into every important seaport of Europe.

The balanced rudder, shown in Figure 2 of Plate I, is one of the important and valuable features introduced into the design of this vessel by its inventor, Mr. R. L. Stevens.

The hull of the ship is double, the inner and outer skins being separated, as shown in Figure 3, by a space varying from 22½ inches at the bottom to 6½ inches at the top of the inner portion. Seven transverse bulkheads are built, dividing the ship into distinct watertight compartments. Two additional bulkheads are carried across the ship below the berth deck. Coal bunker bulkheads, forward and aft, and the several smaller bulkheads in the extreme ends of the vessel, still further strengthen the structure, and assist in securing

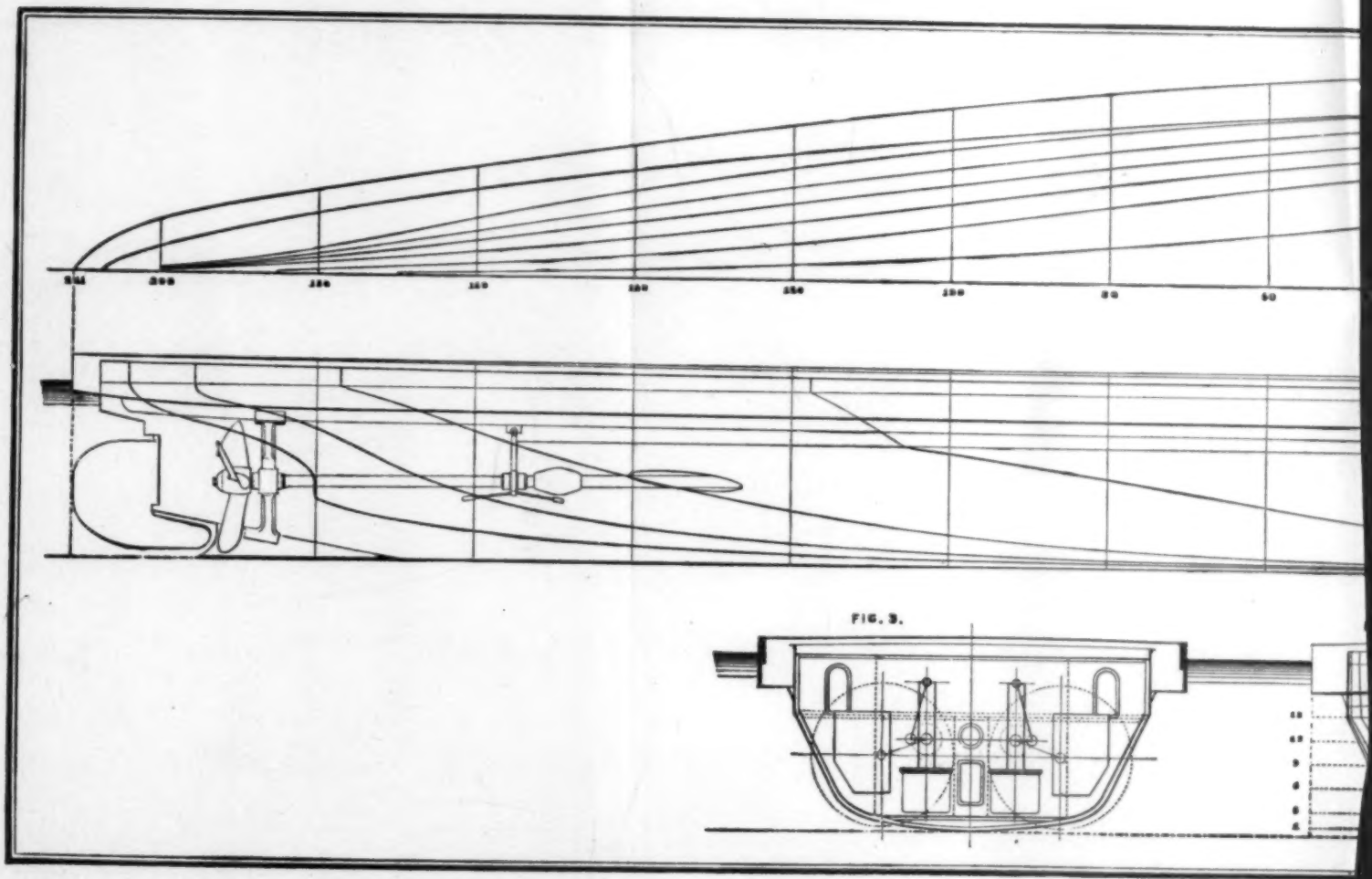


FIG. 3.

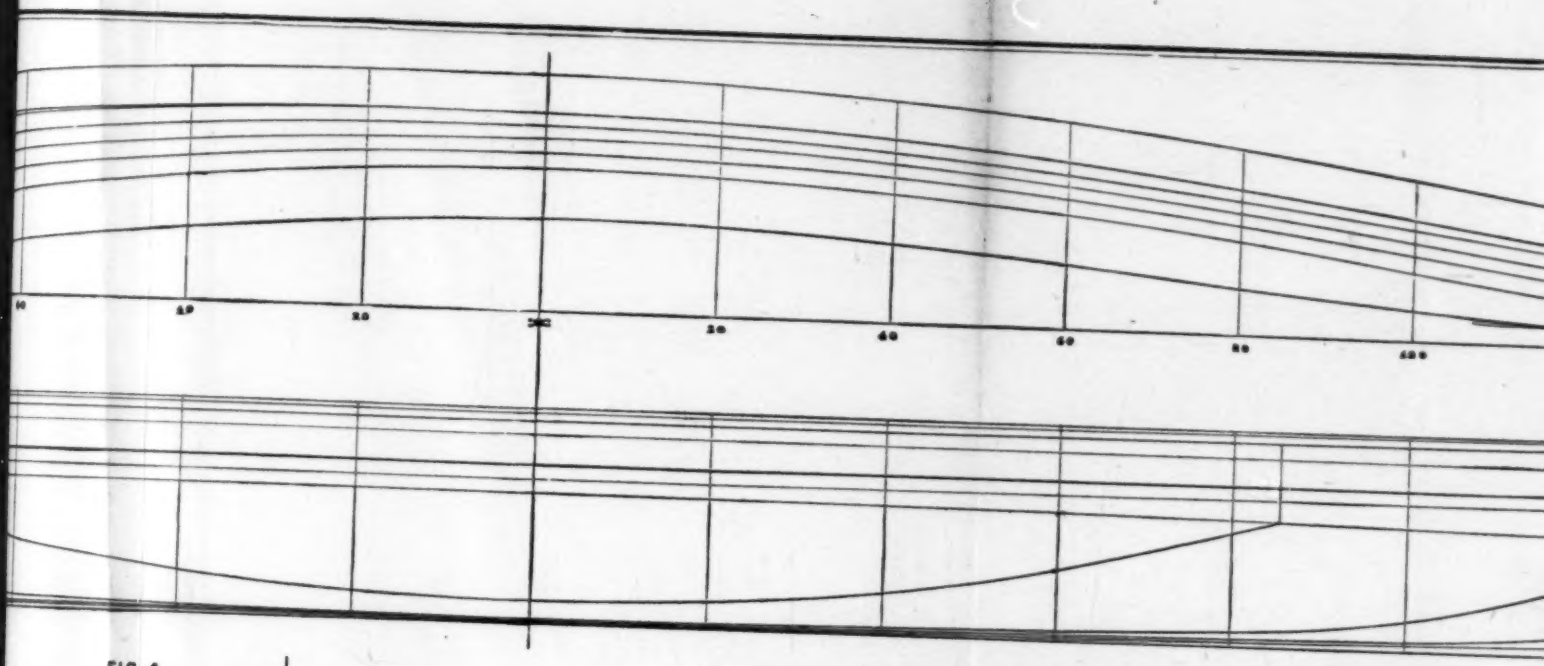
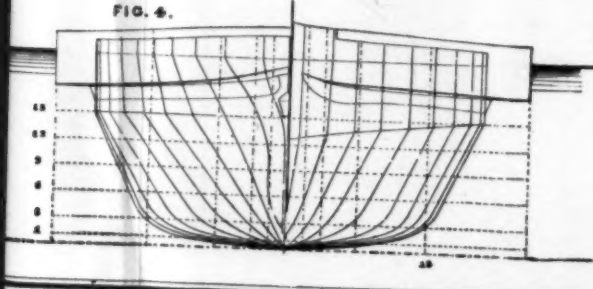


FIG. 4.



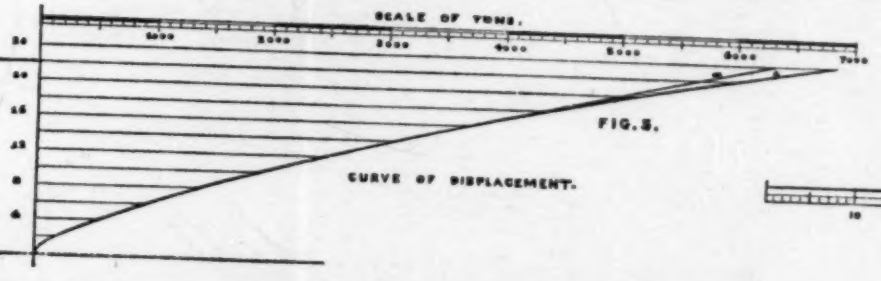



FIG. 5.

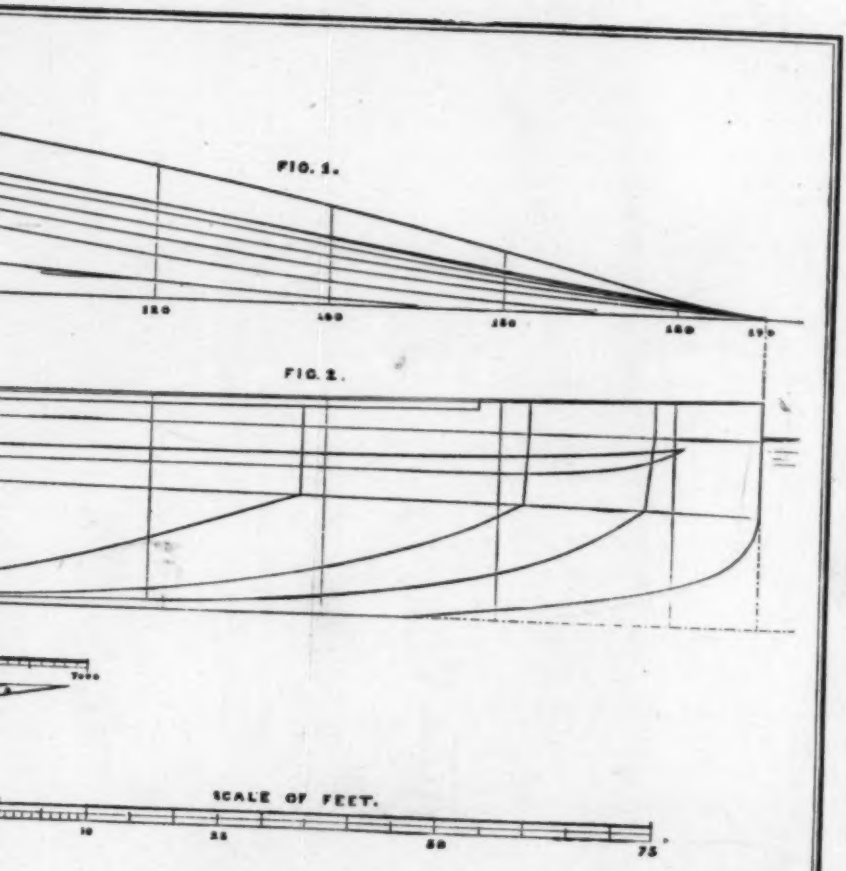
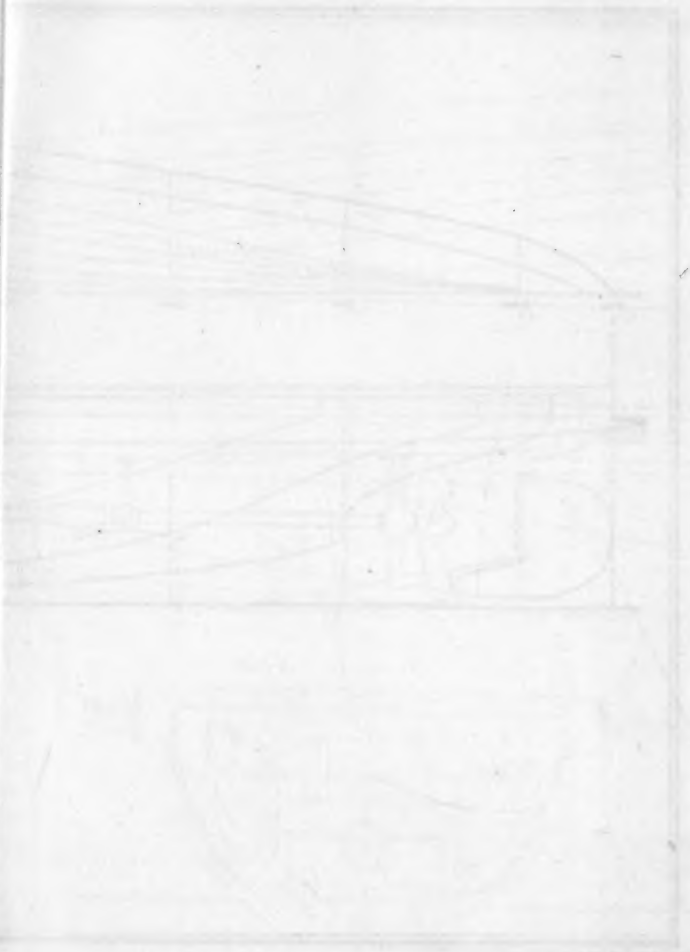
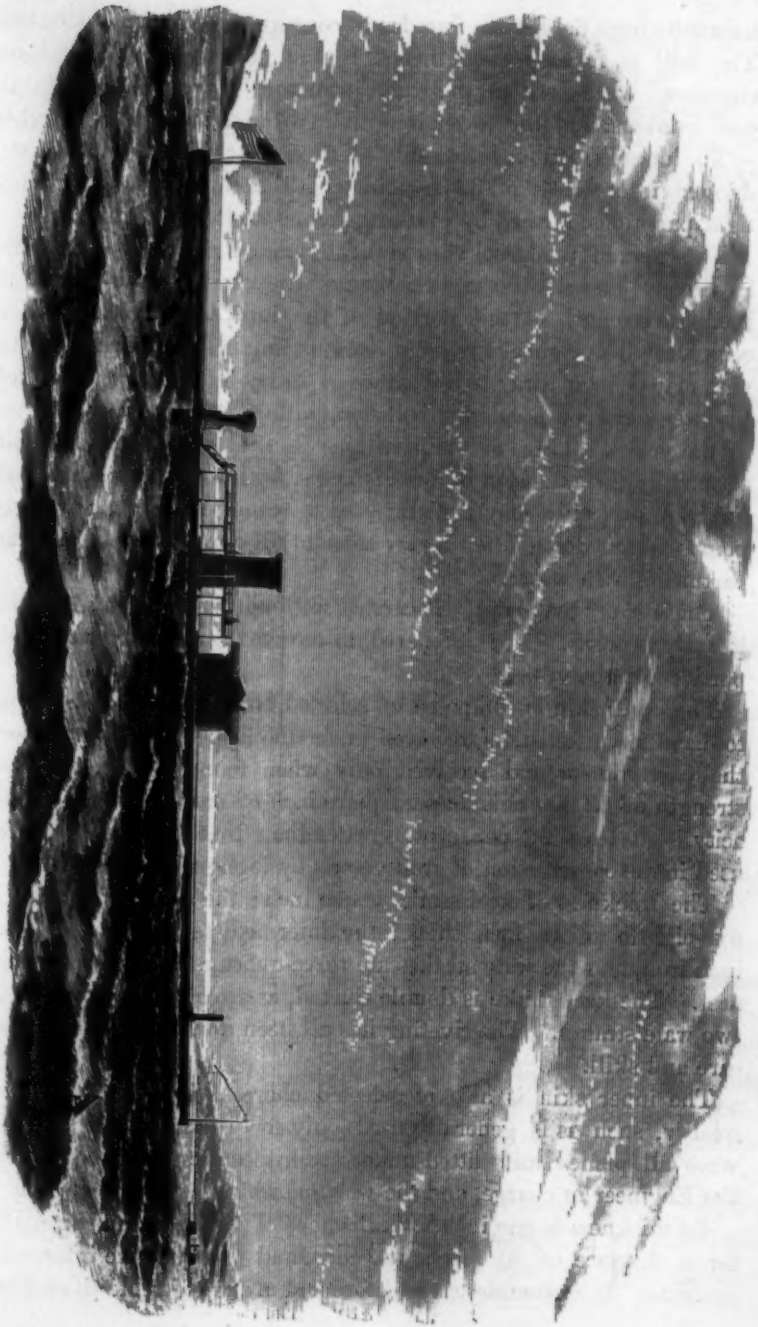



PLATE I.





immunity from liability to founder in consequence of injury to the hull. The hull is further strengthened by the bulkheads of the "turret chamber," which stiffen the whole structure by tying the decks, the coal bunkers, and the lower longitudinal bulkheaks firmly together.

The double bottom is not only made water-tight as a whole, but is divided into spaces of 32 feet in length each, separated by water-tight partitions, formed by caulking-frames and cross-floors.

The Stem of the vessel rises vertically, and is of a section ten inches by three. The cell-like construction of the vessel behind it, and the immense strength of this portion of the hull, will enable it to receive very heavy shocks without serious injury. The whole of this part may be torn away to a distance of thirty-five feet from the stem, by intentional or accidental collision, without endangering the safety of the vessel. Three of the partitions in the bow being horizontal formed by the extension of breast-hooks, back to the transverse bulkheads, a projectile may penetrate, or a seam may start, at any one point without doing other injury than to fill one of these small compartments with water.

The stern "overhang" is carried well out over the rudder, which it fully protects. It is prepared to receive armor plating like other portions of the vessel.

The outer skin is composed of selected boiler plate, which is stated to have been tested, as received under the inspection of an officer of the Government, and received only when found to have a tensile strength of 62,000 pounds per square inch of cross section. Its tenacity is at least 20 per cent. greater than that of iron customarily used in the construction of iron vessels by foreign builders.

The thickness of keel strake is one inch; the garboard strakes are five-eighths of an inch thick; the intermediate strakes are of half-inch iron, and the wale strakes are three-quarters of an inch in thickness. The keel strake is double riveted, as are also the garboard and two wale strakes. The riveting has all been done by hand with both care and skill.

The inner skin is also of selected charcoal iron, of "C No. 1" quality, such as is generally used only for boiler plate. Its joints were all planed and fitted under the inspection and the direction of the Engineer in charge, and the workmanship is unexceptionable.

Its thickness is one inch for a distance of 193 feet amidships, $\frac{1}{2}$ inch for a distance of 30 feet at the ends, and $\frac{3}{4}$ inch at the intermediate portions. It is double riveted fore and aft, with treble riveted butt-

straps for 240 feet amidships. The inner skin is carried up to the fourteen feet line and is made water-tight throughout, as already stated, permitting the rupture of the outer skin without endangering the safety of the vessel. This, with the division of the whole into short water-tight spaces by caulking the frames, is an insurance against even loss of trim by the penetration of the water throughout the space between the two hulls.

The main deck is supported by heavy yellow pine deck beams, of scantling 14x14 and 16x14 inches, spaced usually 36 inches between centres. They rest, at each end, upon a heavy and very strong iron shelf, which serves also to strengthen the ship as a stringer. The beams are also secured to the skin of the vessel by strong iron knees, as seen in Plate VI. They are intended to be supported in the middle by a line of iron stanchions not yet in place. This deck is planked with selected Southern yellow pine, free from sap, shakes or other defects, and thoroughly seasoned. Its thickness is 8½ inches throughout.

MAIN ENGINES AND BOILERS.—GENERAL DIMENSIONS.

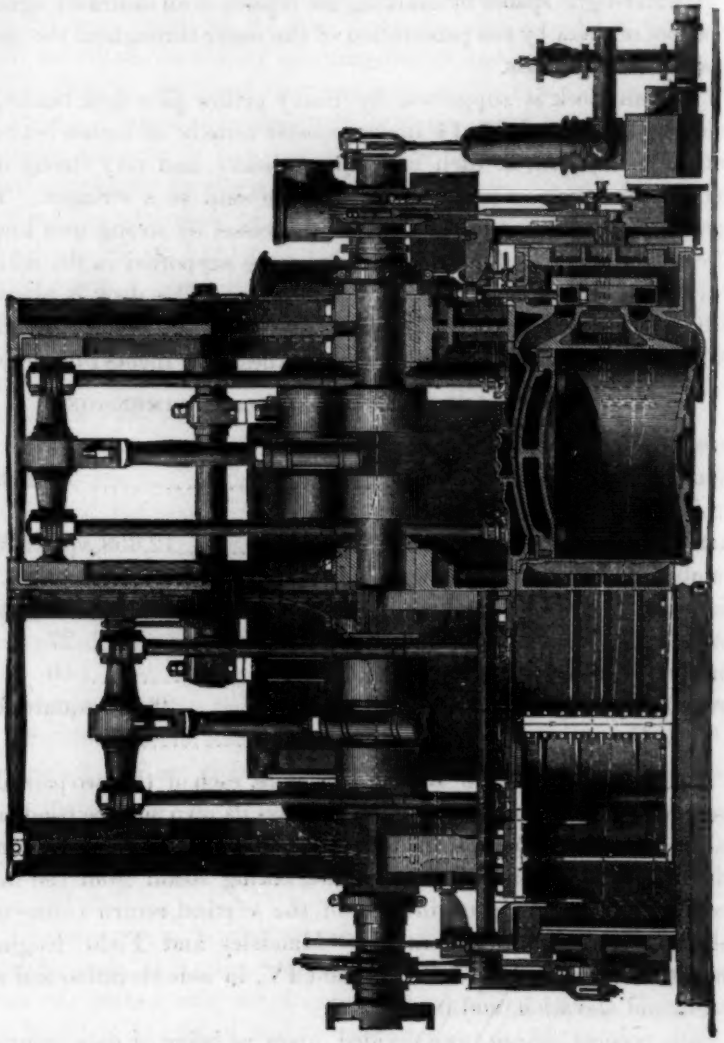
| | |
|---|---|
| Number of Steam Cylinders | 4 |
| Diameter " " | 72 inches. |
| Stroke of Piston | 45 " |
| Surface Condensers, refrigerating surface | 12,650 square feet. |
| Number of Screw Propellers | 2 |
| Diameter " " | 18 feet. |
| Pitch " " | 27 " |
| Number of Boilers | 10 |
| Area of Heating Surface | 28,000 square feet. |
| " Grate " | 876 " |

The Main Engines are arranged in pairs, each of the two pairs driving a screw independently. Each pair has its own surface condenser and its own set of pumps, including a centrifugal circulating pump, driven by a small independent engine, taking steam from the main steam pipe. The main engines are of the vertical return connecting rod type, formerly known as the "Mandsley and Field Engine." They are shown, in Plates II, III, and IV, in side elevation and section in end elevation, and in plan.

This general design was decided upon as being at once compact, readily accessible, and convenient in operation, and as "stowing" well in a ship of which the form was too fine to admit of twin engines of other types. The steam cylinders are four in number, 72 inches in

diameter, and having a stroke of piston of 3 feet 9 inches. The Main Valve is a balanced three-ported slide, having a maximum throw of sixteen inches. The valve is operated by a Stephenson

PLATE II.



Link, as shown in Plate III. Expansion is obtained by means of a "gridiron" valve, situated at one side of the main valve chest, as shown in Plates II, III, and IV, and driven by its own eccentric. The

Connecting Rods are 7½ feet long, 7½ inches in diameter in the neck, and 8½ inches diameter in the middle. These rods, which seem to

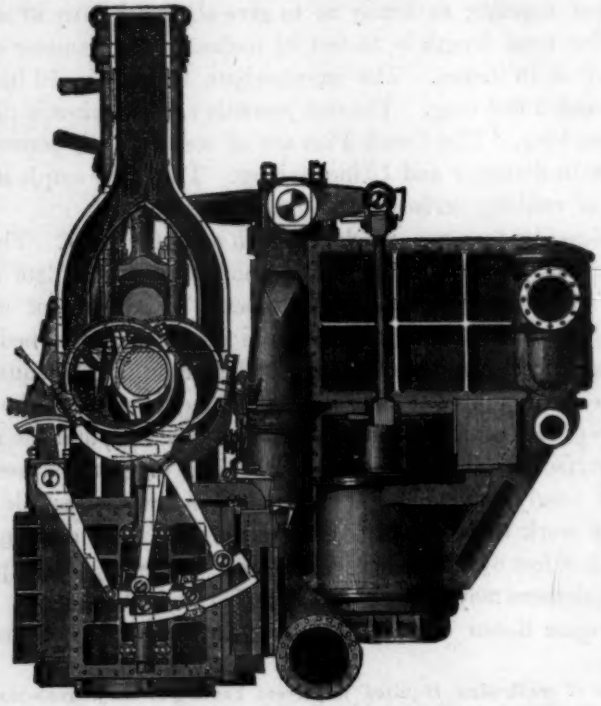


PLATE III.

be as lightly proportioned as any part of the engine, have ample strength to resist any pressure which can be thrown upon them in regular work.* At their upper ends, they are fitted with straps, and are set up by means of the common taper key. At the lower end they have caps secured by bolts and nuts.

*The proper size for such an engine is calculated, with a fair degree of approximation, by the formula . . .

$$d = \sqrt[4]{\frac{D^2 p L^2}{6000}} + 0{\cdot}0125\ D\ ;\ \text{or}\ d = \sqrt{\frac{D\ l.\sqrt{p}}{8{\cdot}8}} + \frac{D.}{80}$$

This formula has been found by Professor Thurston to be a very satisfactory one. In the present case, $d = \sqrt{\frac{72 \times 7\frac{1}{2} \times \sqrt{15+25}}{8{\cdot}8}} + \frac{1}{8} = 7{\cdot}5$. Taking Van Buren's constants and Rankine's more intricate formula,

$$d = 0{\cdot}00527\ D\sqrt{p\left(1 + 0{\cdot}00133\ \frac{L}{D^2}\right)}$$ we get,

$$d = 0{\cdot}00527 \times 72 \times \sqrt{(25+15)\left(1 + 0{\cdot}00133\ \frac{90^2}{7{\cdot}42}\right)} \times 8 = 7{\cdot}4 \text{ inches.}$$

The Crank Shafts are forged in three pieces, connected by crank-pins and cranks, which were forged separately, carefully fitted, and then forced together so firmly as to give all the rigidity of a single piece. The total length is 24 feet 9½ inches. The diameter of each crank-shaft is 16 inches. The intermediate bearing is 16 inches in diameter and 3 feet long. The end journals are 16 inches in diameter and 2½ feet long. The Crank Pins are of steel. Their journals are 15 inches in diameter and 15 inches long. They have ample strength and area of rubbing surface.*

A Surface Condenser is attached to each pair of engines. The tube-plates are in place, and the whole condenser is complete and in position, with the exception of the tubes. These are not ordered. The total area of refrigerating surface in each is designed to be 6,325 square feet, or a total for both condensers of 12,650 square feet. The ratio of this area to that of the heating surface of the boilers is $\frac{12650}{28000} = 0{\cdot}449$, of which the inverse ratio is 2·29, and the ratio of cooling surface in the condensers to the area of grate surface in the boilers is nearly 14½ to 1. This area is more than ample for the amount of work to be done. Each condenser is to contain 4,198 tubes, each 9 feet 6¾ inches long and ⅝ inch diameter. The position of the condensers may be seen in Plates III and IV.

The Engine Room occupies 35½ feet in the length of the vessel

*The size of crank-pins required to prevent heating of the journals may be determined with a fair degree of precision by either of the formulæ given below

The total pressure on each crank-pin bearing would be at a maximum, $4071{\cdot}5 \times 25 = 101,787{\cdot}75$ pounds.

$$l = \frac{P\,V}{60{,}000\,d} = 28{\cdot}8. \qquad \text{[Thurston, 1862.]} \qquad [1]$$

$$l = \frac{P\,(V+20)}{44.800\,d} = 41{\cdot}8. \qquad \text{[Rankine, 1865.]} \qquad [2]$$

$$l = \frac{P\,N}{350.000} = 18{\cdot}9. \qquad \text{[Van Buren, 1866]} \qquad [3]$$

$$l = \frac{I\,H\,P}{130\,s} = 11{\cdot}6. \qquad \text{[Skeel, 1873.]} \qquad [4]$$

The first two formulæ give what are considered by their authors fair working proportions, and the last two minimum length, for iron pins.

Formula [1] was obtained by observation of crank pins of naval screw engines, and [2] by observing locomotive practice in which greater liability exists of annoyance by dust, and greater risk occurs from inaccessibility while running. The latter formula is therefore not well suited for marine practice.

Steel can usually be worked at nearly double the pressure admissible with iron running at similar speed, and the proper length for those here considered would be about $\frac{28{\cdot}8}{2} = 14{\cdot}4$, a length which they exceed. These pins should, therefore, run without water, a somewhat unusual thing with engines of large size.

very nearly amidships. The directions of the shaft lines are divergent, as seen in the plan, Plate IV, their centre lines being 10¾ feet apart at the engines, and 16 feet 8½ inches at their outer ends, a divergence of 0·4366 inches per foot.

The Screws are of cast iron, and of the form shown in Plate V. They are three-bladed, "true screws," having a diameter of 18 feet, and a pitch of 27 feet. The length of hub is 3½ feet, its diameter 34 inches. The total area of each blade is 27·197 square feet, of each screw 81·59 square feet, and of each "screw disc," 254·47 square feet. The engines are arranged to turn them in opposite directions.

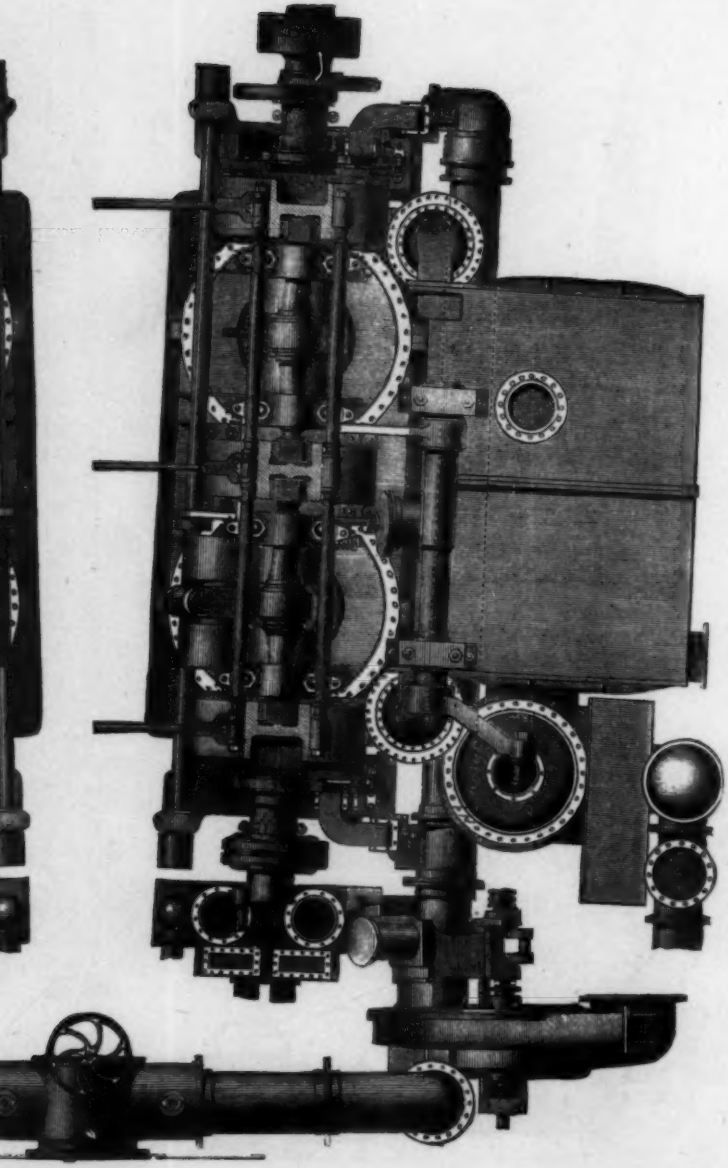
Blowing Engines and Fans are in place at the after end of the engine-room, and at the forward end of the boiler room. These fans are each 8 feet in diameter and are each driven by one engine having a steam cylinder of 16 inches diameter and 14 inches stroke of piston. Two very large blowers are also on hand and ready to be mounted in the space below the turret, where their driving engines are set up. They are 5 feet 2½ inches in diameter, and have a breadth of face of 3 feet 8½ inches. Their driving engines are single, with steam cylinders 16 inches diameter and 14 inches stroke of piston.

The Anchor Hoisting Engines have been completed and set up in their place over the chain locker, immediately abaft the armored bulkhead near the bow. The cylinders are 14 inches diameter and 14 inches stroke. The anchor hoister, or windlass, has not been built. A design was prepared, under the direction of the Consulting Engineer, by the late F. S. Thayer, of the Stevens Institute of Technology, which may be used, if considered suitable by the purchaser of the vessel.

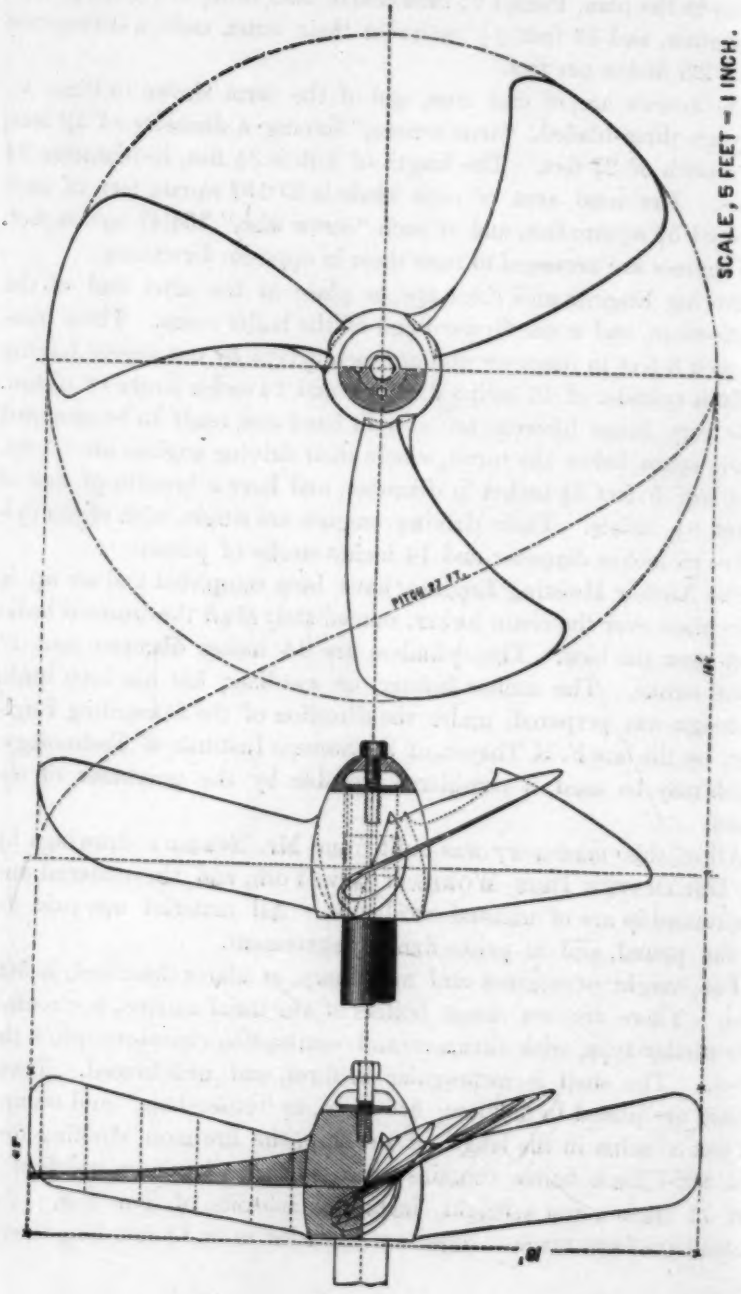
All of this machinery was built from Mr. Newton's drawings by the DELAMATER IRON WORKS of New York, and the material and workmanship are of unusual excellence. All material was paid for by the pound, and at prices fixed by agreement.

The weight of engines and machinery, as above described, is 500 tons. There are ten steam boilers of the usual marine, horizontal, fire-tubular type, with furnaces and combustion-chambers below the tubes. The shell is rectangular in form, and well braced. These boilers are placed in one long fire-room, or "stoke-hole," and occupy 83 feet 8 inches in the length of the ship, the fire-room running fore and aft. Each boiler contains three furnaces, having a width of 3 feet 11 inches, and a height, including ash-pits, of four feet. No grates have been made. They are intended to be 8½ feet long in the

Stevens Iron-clad Battery. Plate IV.



## Plate V.



after, and 6½ feet in the forward boilers. The distance from the grate to the crown of the furnace is intended to be 23½ inches in front, and 30 inches at the back end.

The front of each boiler is 13 feet 10 inches in length, and 14 feet in height. The depth from front to rear varies from 11½ feet in six boilers, to 10 feet 1½ inches in the two forward ones; the depth in intermediate boilers being 11 feet. Each boiler contains 432 tubes of 2½ inches exterior diameter, and from 7 to 9 feet long. The upper row of tubes is six feet below the top of the boiler. The total area of grate surface is 876 square feet.

The heating surface has a total area of 28,000 square feet, distributed as follows:

| | | |
|---|---|---|
| Tubes | 23,380 | square feet. |
| Furnaces | 2,050 | " " |
| Connections | 1,890 | " " |
| Tube Sheets | 680 | " " |
| Total | 28,000 | " " |

Ratio of heating to grate surface.....32 to 1.

This high ratio of heating to grate surface should give great economy of fuel.

These boilers have been tested with cold water under sixty-six pounds pressure per square inch. Their total weight, including valves and pipes, is 255 tons.

The steam power of the boilers is sufficient to supply moderately economical engines of greater size than those to which they are to furnish steam. The range ordinarily observed in marine practice is from 2·5 to 5·0 feet of heating surface to each indicated horse-power, and from 0·1 to 0·2 square feet of grate surface for each horse-power, with forced draught.

Under such extreme conditions, these boilers would supply steam for from 5,600 to 11,200 I. H. P., if estimated by heating surface, or for 4,380 to 8,760 I. H. P., as estimated from the area of grate. The more favorable conditions are those exhibited in the best of recent practice in marine engineering; the less favorable are those ot the practice of twenty years ago.

The coal bunkers are arranged in three groups,—abaft the engines, between the engines and boiler compartments, and forward of the boilers. They are made water-tight, and can be emptied and filled with water at pleasure. They have a total capacity for 800 tons of coal.

A forced draught is secured by making the fire-room air-tight and forcing in the air required to support combustion by means of the blowing apparatus already described. This method has been proven —if the personal experience of the Consulting Engineer on large naval steamers, etc., can be relied upon—to be much more effective and convenient, and far more comfortable than the old plan of leading the air directly to the ash-pits through closed pipes. This plan was introduced many years ago by the late Robert L. Stevens. It is now becoming frequently adopted.

With such proportions as have been given these boilers, and with the arrangements here adopted, a good result should be obtained with a consumption of twenty pounds of coal, or more, per square foot of grate per hour.

The total length in the ship occupied by engine and boiler-room is 119 feet 8 inches. The total weight of propelling apparatus and machinery is, approximately, the following:

| | |
|---|---|
| Engines, shafts, screws | 500 tons. |
| Boilers and attachments | 255 " |
| Water in Condensers | 25 " |
| " Boilers | 200 " |
| Total | 980 tons. |

No steps have yet been taken in the construction of either armor or armament. It was proposed to cover the main deck with plating 1½ inches thick fore and aft.

The side armor is shown in section, in Plate VI, which also illustrates the construction of the armor shelf and backing, which are constructed and ready to receive the armor. The side armor is to surround the vessel, except at the bow. Thirty-five feet from the stem, a heavy transverse bulkhead meets the side armor and carries the same thickness of protecting plating, and a similar arrangement of backing. The thickness of armor plating proposed is ten inches from the level of the main deck down to a line four feet below, and thence five inches to the lower edge of the armor shelf.*

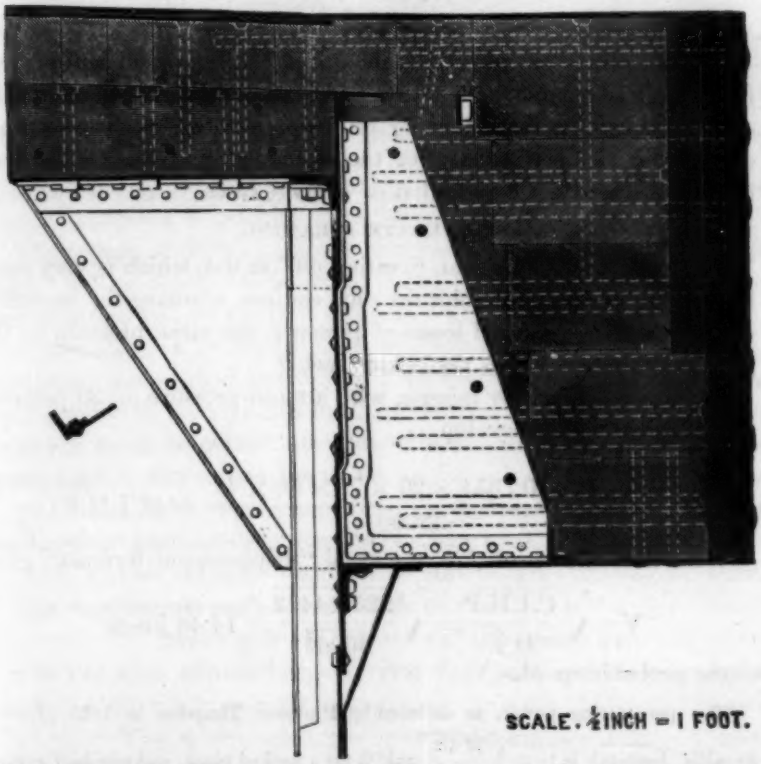
The backing is of wood, 44 inches thick. The inner course is of white oak, in heavy balks set on end, and thoroughly secured by a large number of bolts. The outer portion is of yellow pine timber laid horizontally and well scarphed together. The upper portion of

*The armor, as preferred by the Consulting Engineer, may be made considerably thicker where protecting the machinery and given a correspondingly reduced thickness at stem and stern.

the armor is also backed by the whole structure of the heavy main deck, against which the upper portion of the armor backing proper rests. The side of the vessel exposed above water can thus be made capable of resisting far heavier blows than it would be likely to receive in action from any guns afloat.

As a security against decay, the backing has been saturated with crude creosote, which was shown by Professor Renwick, and which has

PLATE VI.




been proven by subsequent experience, to be an effective defence against the teredo as well as against rot.

The turret has not been constructed, and no detailed plans have yet been prepared. A turret has been proposed thirty feet in diameter, and the Engineer has estimated on a thickness from 16 to 18 inches, the precise figure to be determined by the amount of other weight carried. The heaviest armor yet made abroad is 14 inches, and in our own navy 15 inches.

The guns first proposed were two XX-inch U. S. naval smooth-bored guns, weighing 95,000 pounds each, throwing a shot weighing 1,040 pounds, with a charge of 200 pounds of powder. Rifles of XII-inch bore, throwing shot of equal or greater energy, would probably be considered far preferable by the majority of ordnance officers. The energy of a shot of the latter description, on leaving the gun may be estimated at about 10,500 foot-tons, and its penetrating power is sufficient to destroy plating 17 and 25 inches in thickness, with and without backing respectively.*

## Speed and Engine Power.

The fine lines of this vessel should give a high coefficient of performance, and enable high speed to be attained with comparatively small power. In the following estimate, however, it has been assumed that the performance of the machinery and the efficiency of the vessel would not exceed that of average cases.

### MODERATE STEAMING.

With 20 pounds of steam, "cutting off" at 0·4, which is very nearly the most economical point for such engines, allowing for imperfect vacuum and other usual losses of pressure, the mean pressure on the piston will be 20 pounds per square inch.†

At 60 revolutions per minute, with a mean pressure of 20 pounds, these engines would develop

$$\frac{72^{-2} \times 0{\cdot}7354 \times 20 \times 7\tfrac{1}{2} \times 60 \times 4}{33000} = 4442 \text{ I.H.P.}$$

With a coefficient of 225, the usual "displacement formula" gives

$$V = \sqrt[3]{\frac{\text{C.I.H.P}}{D^{\frac{2}{3}}}} = \sqrt[3]{\frac{225 \times 4442}{6006^{\frac{2}{3}}}} = 14{\cdot}46 \text{ knots}$$

as the probable speed.

*The penetrating power, as deduced by Professor Thurston in 1870 (*Journal Franklin Institute,*) is $t = \frac{\sqrt{W V^2}}{400.000\, d} = 17{\cdot}3$ for a backed plate, and one-half greater thickness, when unbacked, may be fractured.

†The mean pressure of steam in the cylinder of a steam engine may be determined for ordinary practice, such as is here considered, by the formula:

$$p = P\,\frac{1 + A \log \varepsilon}{\varepsilon} - B - C\,P;$$

in which $p$ represents mean pressure, P the boiler pressure, and $\varepsilon$ the ratio of expansion. The constants, as determined many years ago by Mr. Francis B. Stevens, are $A = 2{\cdot}3$; $B = 5$; $C = 0{\cdot}06$.

Taking C = 600 in the other, or "midship-section formula,"

$$V=\sqrt[3]{\frac{C.I.H.P}{M}}$$ we obtain $$V=\sqrt[3]{\frac{600\times4442}{890}}=14{\cdot}41 \text{ knots}$$

Again taking the formula $$V=\tfrac{1}{2}\left(\sqrt[3]{\frac{C.I.H.P}{M}}+\sqrt[3]{\frac{C'IHP}{D^{\frac{2}{3}}}}\right),$$

using C = 600, C′ = 225, the estimate becomes 14·43 knots.

We should be justified probably, in taking higher coefficients of performance, since the quotient $$\sqrt{\frac{\text{length}\times\text{breadth}}{\text{draught}}}=\sqrt{\frac{390\times45}{22}}=6,$$ bears very nearly the most economical relation to the ratio $$\frac{\text{length}}{\text{breadth}}=\frac{390}{45}=8{\cdot}67$$ for vessels of great speed.

The lines of the vessel are unusually fair and fine, and may be taken for purposes of calculation as "wave lines."

The armor shelf will impede the vessel somewhat when "out of trim," but no reason exists for supposing that the Rankine method of computation will not apply to this case. The unusually large proportion of skin area to displacement will rather tell against the vessel. Adopting the method here referred to, the "wetted surface" of the hull is found to be very closely 22,462 square feet, at 22 feet draught, to which must be added the area of horizontal surface beneath the armor shelf, 3,060 square feet.

The "coefficient of augmentation," as deduced by measurement of the angle of greatest obliquity of the water lines, Plate 1, is

$$C=1+4\,\text{Sin}^2\theta+\text{Sin}^4\theta=1{\cdot}1$$

The "augmented surface" is therefore

$$22462\times1{\cdot}1+3060=27768 \text{ square feet.}$$

The probable attainable speed, with 4442 indicated horse power is

$$V=\sqrt[3]{\frac{20{,}000\times4{,}442}{27{,}768}}=14{\cdot}73 \text{ knots.}$$

The average of these estimated speeds is 14·5 knots, which may be considered to represent *the speed of the vessel without driving*. It should be readily attained, using eight boilers, and may be reached with but six.

The Slip of the screws, when steaming 14½ knots, with 60 revolutions of the engines, would be 9·1 per cent.

For vessels of fine lines and high speed, with well designed propel-

ling apparatus, the slip has usually been estimated, by Professor Thurston, at four times the ratio of area of midship section to that of screw-disc. The total disc-area of these screws is $254{\cdot}4\times2=508{\cdot}8$ square feet, which is equal to $\frac{508{\cdot}8}{890}=0{\cdot}57$ of the area of greatest immersed section, an unusually high ratio, and a proportion which should give great economy of propelling power. Using the rule above referred to, the slip would be estimated at $S=4\frac{M}{A}=4\frac{890}{509}$ $=7$ per cent., a figure not often found, except with badly shaped vessels, which sometimes give "negative slip." This is as should be expected, since the vessel has double the screw disc area obtainable in ships with single screws. The estimates which have been given contemplate the possibility of thirty per cent. greater slip.

### MAXIMUM SPEED, CONTINUOUS STEAMING.

The provision here made for forced draught should, as has been stated, enable 20 pounds of coal to be burned per hour on each square foot of grate, and the high ratio of heating to grate surface should insure economical use of fuel at exceptionally high rates of consumption. Steam can be furnished continuously to drive the engines 65 revolutions per minute, and 68 or 69 revolutions, with a mean pressure of between 25 and 26 pounds per square inch, and 6,500 indicated horse-power, giving a speed of 16½ knots, may be obtained for the periods of time during which clean fires can be kept. With a boiler pressure of 25 pounds, and expanding as before assumed, the mean pressure in the cylinder would be 23½ pounds. With this pressure, at the speed here taken, 65 revolutions per minute, the engines would develop

$$\frac{\frac{3}{4}72\times0{\cdot}7854\times23\frac{1}{2}\times7\frac{1}{2}\times65\times4}{33{,}000}=5654 \text{ I.H.P.}$$

which power has a ratio to heating surface of boilers of $\frac{5654}{28000}=0{\cdot}202$, a ratio which is well inside of ordinary practice.

The maximum speed, assuming the maximum power to be but 5,654 indicated horse power, will be—

By augmented surface, $V_1=\sqrt[3]{\frac{20{,}000\times5654}{27{,}768}}=15{\cdot}97$ knots.

By midship section, $V_2 = \sqrt[3]{\frac{600 \times 5654}{890 \cdot 26}} = 15 \cdot 62$ knots.

By displacement, $V_3 = \sqrt[3]{\frac{225 \times 5654}{6006}} = 15 \cdot 67$ knots.

The mean of these estimates may be taken as the probable *maximum speed for continuous steaming*. This is 15·75 knots. The slip becomes 8·895 per cent. slightly less than that obtained for 14½ knots, as it should be at the higher speed. No armored vessel in any navy has the speed here found for this ship, or approaches it. The fastest yet constructed has a sea-going speed at least a knot less, and the fleetest unarmored vessel in any foreign navy has less speed by three-quarters of a knot. The speed of 16½ knots, which is considered as attainable under most favorable circumstances, exceeds that of any recorded trial performance of even the British iron-clad "Monarch," the fastest of the fleet, by more than 1½ knots per hour.

Weights would probably be distributed as follows:

| | |
|---|---|
| Hull (including bulkheads, etc.) | 2,250 tons. |
| Machinery and Boilers | 755 " |
| Coal | 800 " |
| Stores and other weights | 700 " |
| Armor (side and deck) | 1,020 " |
| Turret and Pilot House | 400 " |
| Guns | 80 " |
| Total | 6,005 " |

The following is the Speed, Time, and Distance table, as estimated for the ship, at the draught, and with the co-efficients of performance as already given. The figures are given as a probably close approximation. Coal 800 tons:

| Speed in Knots. | I. H. P. | Coal per hr. per I. H. P. lbs. | Hours Run. | Days Run. | Distance, Miles. |
|---|---|---|---|---|---|
| 16 | 6000 | 2¾ | 109 | 4·67 | 1744 |
| 15 | 5000 | " | 130 | 5·41 | 4850 |
| 14 | 4000 | " | 163 | 6·78 | 2282 |
| 12 | 2000 | 3 | 299 | 12·46 | 3488 |
| 0 | 1200 | 3½ | 427 | 17·79 | 4270 |
| 8 | 800 | 4 | 560 | 23·33 | 4480 |
| 6 | 600 | 4½ | 876 | 29·82 | 5256 |

The present capacity of coal bunkers is here taken on the assump-

tion that it will be preferred to devote all surplus displacement to floating the maximum amount of armor, since it is probable that no long voyage will become necessary at full speed.

At the speed considered most economical for a naval vessel between stations, 6 knots, the number of hours steaming would be 876, or, a run of thirty days could be made, accomplishing a distance of 5,256 miles without coaling. At this speed, the engines are estimated as consuming $4\frac{1}{2}$ pounds of coal per horse-power per hour, as such large engines would fall off greatly in economy when developing such low power.

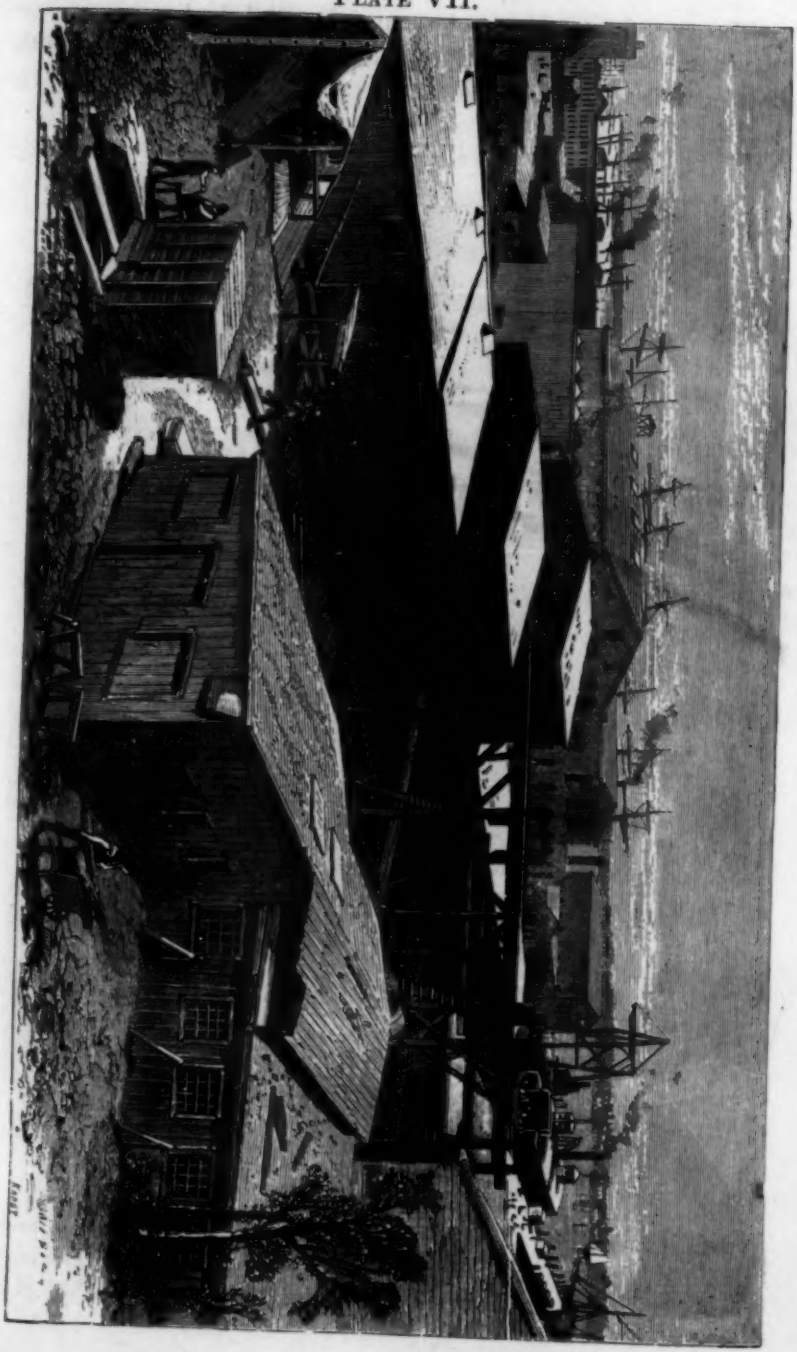
The lines of the vessel, and the form of the transverse sections, are calculated to give moderately easy motion in a sea-way. The stability is very great, and her motion would be quick, and somewhat uneasy if completed with high free-board. All vessels of the monitor class, however, are found to behave well in the heaviest seas, even when not peculiarly well shaped. The height of the metacentre above the centre of buoyancy, is 11·72 feet, and is 2·85 feet above the load line. The Moment of Stability at a heeling angle of 15 deg., is $6{,}000 \times 11{\cdot}72 \times 0{\cdot}2588 = 18{,}200$ foot-tons, a higher value than is often obtained. This great moment of stability is largely due to the projection of the armor shelf.

The strength of general structure, the peculiar construction of the bow, and the great power of the vessel, make it a very effective Steam Ram. Steaming at full speed, and striking another vessel at rest, the energy exerted would be $E = \frac{WV^2}{2g} = 60{,}000$ foot-tons nearly, or sufficient to raise the weight of the whole vessel ten feet. This is equal, in effect, to that of eight or nine 600-pound rifle, or six XX-inch round shot, discharged simultaneously on the same spot. It is more than equal to the estimated energy of the projectiles of four of the proposed "81 ton rifles," recently designed by the British Admiralty. Such a blow would crush in even the armor-plated sides of any iron-clad yet constructed. The "handiness" of the vessel gives a facility in manœuvering which is a most essential advantage in the "ram."

The vessel lies in a dry dock at Hoboken, N. J., separated from the Hudson River by a bulkhead.

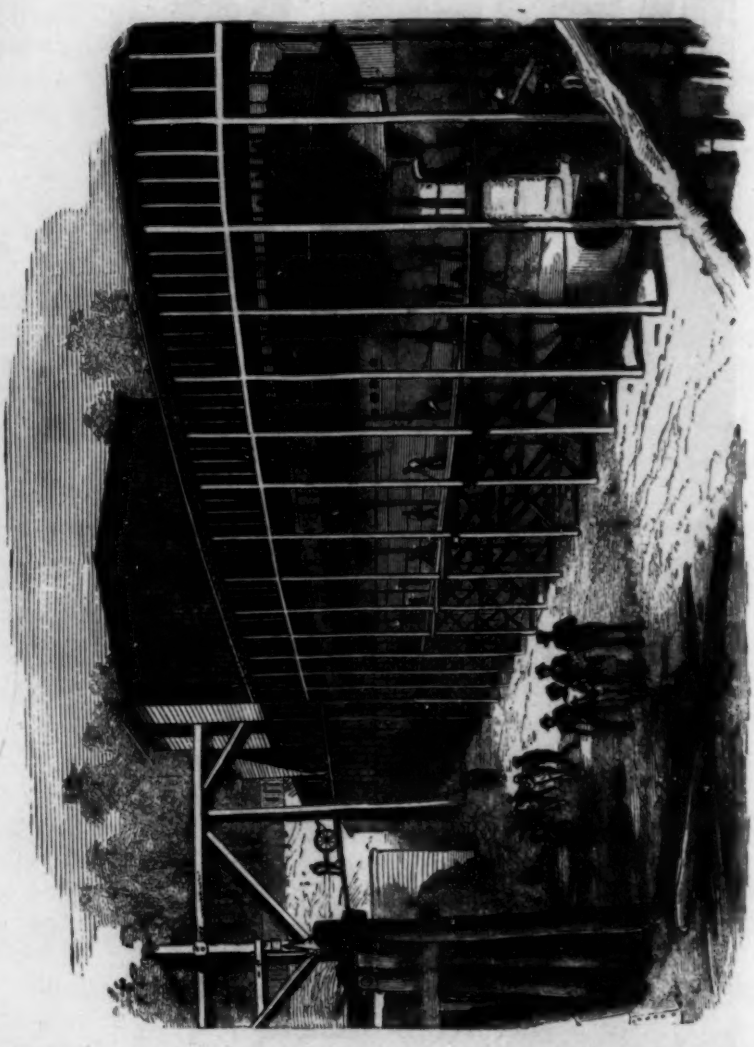
A machine shop is situated by the side of the dock, and several sheds which have been used for storage are within the enclosure. The city of New York lies directly opposite. The distance across the Hudson at this point is about 1700 yards.

PLATE VII.



The general arrangement of the premises, and the location, are well shown in Plate VII, which represents the vessel as seen from the south-west, and from a stand-point which gives a bird's-eye view. The

PLATE VIII.



vessel is covered by the ship-house seen in the middle ground, and is thoroughly protected against the action of the weather. The trestle frame, leading from the vessel amidships to the machine shop at the

extreme right, has been used in transporting the heavy parts of the vessel and machinery. The slip into which the vessel emerges, on leaving the dry dock, is shown at the right, occupied by a ferry-boat.

The position of the ship in the dock is best shown in Plate VIII, which represents her appearance when nearly completed externally. The stand-point is taken under the stern at the bulkhead, at the end of the dock nearest the harbor, and the view extends to the bow, which lies under the street, running along the western line of the enclosure. The boarding has been removed from the sides of the house to afford a better view of the vessel. These engravings give so accurate an idea of the location of the vessel, and of the arrangement of the premises, that further description is unnecessary.

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## THE THEORY OF AERO-STEAM ENGINES.

By J. A. Henderson, M. E.

[Continued from vol. lxviii., page 113.]

In order to give a clearer idea of the precise mode of obtaining the results given in this table, the calculations in the case of example two are below indicated in full, as they were originally worked out by direct substitution of the data in the formulæ.

### EXAMPLE TWO.

DATA.

$$P_1 = 60 \text{ pounds, } t_1 = 450^\circ \text{ and } N = 18 \text{ pounds.}$$

$$\therefore\ p_1 = 144 \times 60 + 2116{\cdot}4 = 10756{\cdot}4 \text{ pounds per square foot.}$$

$$r\ p = \frac{10756{\cdot}4}{2116{\cdot}4} = 5{\cdot}082 \text{ and } \tau_1 = 450 + 461{\cdot}2 = 911{\cdot}2^\circ$$

RESULTS.

$$\log.\ \tau_b = \log.\ 511{\cdot}2 + 0{\cdot}29 \log.\ 5{\cdot}082$$

$$\therefore\quad \tau_b = 819{\cdot}1 \text{ and } t_b = 357{\cdot}9^\circ \ldots\ldots\ldots\ldots (1)$$

$$\log.\ r_e = 0{\cdot}71 \log.\ 5{\cdot}082$$

$$\therefore\quad r_e = 3{\cdot}172 \ldots\ldots\ldots\ldots (2)$$

$$t_b = \frac{10{,}000{,}000}{772(1+18)\times 0{\cdot}238} = 2864{\cdot}5^\circ \ldots\ldots\ldots\ldots (3)$$

$$t^\circ = 2864{\cdot}5 + 357{\cdot}9 = 3222{\cdot}4^\circ \ldots\ldots\ldots\ldots (4)$$

$$q_b = \frac{3222{\cdot}4 - 450}{450 - 357{\cdot}9} = 30{\cdot}102 \ldots\ldots\ldots\ldots (5)$$

$$w_a = \frac{1+18}{18} = 1.056 \text{ pounds,} \quad \ldots\ldots(6)$$

$$q_v = \frac{0{\cdot}238\ (3222{\cdot}4 - 450)}{1124 + 0{\cdot}475 \times 418 - 100} = 0{\cdot}540 \quad \ldots\ldots(7)$$

$$w_s = 0{\cdot}540 \times 1{\cdot}056 = 0{\cdot}570 \text{ pounds,} \quad \ldots\ldots(8)$$

$$w_1 = 0.570 + 1{\cdot}056 = 1{\cdot}626 \text{ pounds,} \quad \ldots\ldots(9)$$

$$v_a = 53{\cdot}15\ \frac{911{\cdot}2}{10756{\cdot}4} = 4.503 \text{ cubic feet,} \quad \ldots\ldots(10)$$

$$v_s = 85\ \frac{911{\cdot}2}{10756{\cdot}4} \times 0{\cdot}57 = 4{\cdot}104 \text{ cubic feet,} \quad (11)$$

$$q_v = \frac{4{\cdot}104}{4.503} = 0{\cdot}911 \quad \ldots\ldots(12)$$

$$v_1 = 4{\cdot}503 + 4{\cdot}104 = 8{\cdot}607 \text{ cubic feet,} \quad \ldots\ldots(13)$$

$$\gamma_n = \frac{0{\cdot}238 + 0{\cdot}48 \times 0{\cdot}54}{0{\cdot}169 + 0{\cdot}37 \times 0{\cdot}54} = 1{\cdot}348 \quad \ldots\ldots(14)$$

$$\frac{1}{\gamma_n} = 0{\cdot}741 \text{ and } \frac{\gamma_n - 1}{\gamma_n} = 0{\cdot}258$$

$$\log. \tau_2 = \log. 911{\cdot}2 + 0{\cdot}258 \text{ (a. c. log. } 5{\cdot}082)$$

$$\therefore \quad \tau_2 = 599{\cdot}1^\circ \qquad \text{and} \qquad t_2 = 137{\cdot}9^\circ \quad \ldots\ldots(15)$$

$$\log. r = 0{\cdot}741 \log. 5{\cdot}082$$

$$\therefore \quad r = 3{\cdot}336 \quad \ldots\ldots(16)$$

$$v_2 = 3.336 \times 8.607 = 28{\cdot}71 \text{ cubic feet,} \quad \ldots\ldots(17)$$

$$v_a = 53\ 15\ \frac{511{\cdot}2}{2116{\cdot}4} = 12{\cdot}84 \text{ cubic feet,} \quad \ldots\ldots(18)$$

$$q_c = \frac{12{\cdot}84}{28{\cdot}71} = 0{\cdot}447 \quad \ldots\ldots(19)$$

$$q_n = \frac{\frac{1{\cdot}348}{3{\cdot}336} - \frac{1}{5{\cdot}082}}{0{\cdot}348} = 0{\cdot}596 \quad \ldots\ldots(20)$$

$$p_n = 0{\cdot}596 \times 10756{\cdot}4 = 6410{\cdot}8 \text{ pounds per square foot.} \quad (21)$$

$$q_a = \frac{\frac{1{\cdot}408}{3{\cdot}172} - \frac{1}{5{\cdot}082}}{0{\cdot}408} = 0{\cdot}606 \quad \ldots\ldots(22)$$

$$p_a = 0{\cdot}606 \times 10756{\cdot}4 = 6518{\cdot}3 \text{ pounds per square foot.} \quad (23)$$

$$U^n = (6410{\cdot}8 - 2116{\cdot}4)\ 28{\cdot}71 = 123{,}296 \text{ foot pounds.} \quad (24)$$

$$U_a = (6518{\cdot}3 - 2116{\cdot}4)\ 12{\cdot}84 = 56{,}516 \text{ foot pounds.} \quad (25)$$

$$U_e = 124296 - 56516 = 66{,}780 \text{ foot pounds} \quad (26)$$

$$H_1 = \frac{10{,}000{,}000}{18} = 555{,}555 \text{ foot pounds.} \quad (27)$$

$$H_2 = 555{,}555 - 66{,}780 = 488{,}775 \text{ foot pounds} \quad (28)$$

$$P_s = \frac{66{,}781}{28{\cdot}71} = 2{,}326 \text{ pounds per square foot,}$$

or 16·15 pounds per square inch.....(29)

$$P_h = \frac{555{,}555}{28{\cdot}71} = 19{,}350 \text{ pounds per square foot,}$$

or 134·4 pounds per square inch.....(30)

$$E = \frac{66781}{555{,}555} = 0{\cdot}120 \quad \ldots\ldots\ldots\

1. To the effect which would be had upon the work and efficiency of an aero-steam engine, were the air and steam conceived to expand in separate cylinders, their weights, initial pressures and temperatures, and final pressures, being the same as in the mixture; and

2. To the determination of the size of the lifting air-pump for a condensing engine.

Another problem involves the determination of the efficiency of heating-surface of the fire-chamber and connections for injection of air in the boiler, in order to properly provide for the requisite transfer of the remaining heat, by ebullition through the water; but its results more fitly belong with the discussion of the practical form of boiler, not entered upon in the present article.

About the second of these problems enough has been already said, while the practicability of using condensation was being considered.

As the result of the first, it may be stated that in calculations made with the data of several of the previous examples, *the work developed by the separate expansion of the weight* $w_a$ *of air and* $w_s$ *of steam, from the common initial temperture* $t_1$ *and pressure* $p_1$ *to the atmospheric pressure* $p_2$, *was in every case the same as the work already found for the weight* $w_1$ $(= w_a + w_s)$ *of the mixture, expanding with the same values of* $p_1$, $t_1$ *and* $p_2$.

An independent proof of this equality of the work of the mixture to that of the component gases when worked separately under the same conditions as to limiting pressures and initial temperature, doubtless exists, but the essential difference in form between the working diagram of the mixture and that of either the air or steam, renders it difficult to see in any other way than by direct calculation that the equality holds true; the equations of the curves of expansion, the ratios of expansion, and the final temperatures differ in each of the three cases.

A sketch of the theoretic form of diagram applicable to such an aero-steam engine as that under consideration, is represented upon the adjoining page, being a combined diagram of the main and pump cylinders. The corresponding angles are marked by the same letters *A, B, C, etc.*, which when the angles do not coincide, are indexed with the small initial letters of the respective fluids, while the proper values of $\gamma$ are placed adjacent to the adiabatic curves of expansion. The coordinates of the angles are also given, being represented by the symbols for volumes and pressures used throughout the general formulæ.

As the whole cycle of operations has already been described for an engine using the mixture, the combined diagram explains itself and no further description is necessary.

The dotted curves of expansion $B_s\ C_s$ and $B_s'\ C_s'$, are introduced to complete the diagrams of the steam and air when expanded separately, according to the supposition of the problem just enunciated. The equality of work there indicated by numerical calculation, would be represented here by the equality of the area of $A\ B_m\ C_m\ D$, to the sum of the areas of $A\ B_s\ C_s\ D$ and $A\ B_s'\ C_s'\ D$, the area $A\ B_s\ C_s\ D$ of the compressing pump diagram remaining the same for the separate as for the mixed expansion. The effective work developed by an aero-steam engine using the mixture, and represented by the area $B_s\ B_m\ C_m\ C_s$, would be equal to that of a superheated steam engine having $A\ B_s\ C_s\ D$ for its working diagram, added to that of a Joule's air engine having for its diagram of effective work the difference $B_s\ B_s'\ C_s'\ C_s$, between $A\ B_s'\ C_s'\ D$, and $A\ B_s\ C_s\ D$; this is equivalent to saying that the area $B_s\ B_m\ C_m\ C_s$ = area $A\ B_s\ C_s\ D$ + area $B_s\ B_s'\ C_s'\ C_s$,

These statements would seem to apply to any aero-steam engine whatever be the proportion of air admitted.

Previous to concluding our whole subject, some remarks need to be made upon the results hitherto arrived at, more particularly as relating to efficiency. A general explanation of the variation of the efficiency with different values of the data can be made in most cases independently of any direct calculations and may be fitly given prior to an examination of the numerical results of the examples.

By considering according to what has just been stated, the aero-steam engine to be equivalent to the combination of a super-heated steam engine and a Joule's air engine, the explanation may be much simplified, as in the separate engines the variations of work and efficiency can be readily followed out and the results then combined as being applicable to the aero-steam engine.

The quantities directly determining the resultant efficiency E of the mixture, are:

1. The proportion already given as $q_h$, in which the available heat of combustion is distributed between the steam and air, and which affects E by varying the relative amounts of the whole heat to which the separate efficiencies of the steam and air apply, and

2. The actual values of these separate efficiencies which may be denoted by $E_s$ and $E_a$ respectively.

The more important quantities upon which E is dependent, are the initial temperature $t_1$ the boiler pressure $P_1$ and the supply of air N per pound of fuel, which three data it will be remembered are the same as were made subject to change in the different examples.

Both $q_h$ and the separate efficiencies, depend on $t_1$ and $P_1$, but $q_h$ only is affected by changes in N. The variation of E with these data, may thus be expressed:

In all cases E increases with $t_1$ whatever values may be assigned to to $P_1$ or N. The variation of E with $P_1$ and N, depends not only upon the actual values of those quantities, but also upon the relation between $P_1$ and $t_1$, determining the range of temperature $t_1$—$t_b$ for the reception of heat by the air, as follows:

As long as $P_1$ is below, or $t_1$ above the limit necessary to keep $t_1 > t_b$ E increases directly with $P_1$, since $E_s$ rises with the boiling-point, and also since $E_a$ is increased owing to the whole reception of heat by the air being made to take place more nearly at the upper limit $t_1$. At the same time it (E) increases with N, because of the greater actual value of $E_a$ over $E_s$ for the same conditions as to pressures and temperatures. $P_1$ and N cannot however be advantageously increased together, as the more $P_1$ is increased, the smaller becomes the range $t_1 - t_b$, measuring the reception of heat by the air, and the larger must be the supply N, to cause $E_a$ to have effect upon the resultant efficiency.

When $P_1$ is such that $t_b = t_1$, E is independent of N, and the air merely acts as a purveyor of heat from the fire to the steam. E is then the efficiency of steam $E_s$, under the given values of $P_1$, $t_1$ and $P_2$.

If $P_1$ be still further increased or $t_1$ diminished, the range $t_1 - t_b$ becomes negative, indicating that a portion of the heat of compression enters the steam. The efficiency of the steam would continue to increase with $P_1$, because of the elevation of the boiling-point, and of this addition of heat of compression; on the other hand, the air would not only perform no effective work at all, but would absorb a portion of that of the steam, owing to the resistance of the compressing pump exceeding the work re-developed by the air in the main cylinder. In this case the resultant efficiency E of the mixture, according to Professor Rankine's remarks (as well as the numerical results of the present examples,) increases both with $P_1$ and N varied either singly or together, the rate of increase with the latter being directly dependent upon the range $t_b - t_1$.

We may cause E to approach either $E_a$ or $E_b$, by the following changes:

When $E_a$ is desired to predominate, $P_1$ is reduced or $t_1$ increased to extend the range $t_1 - t_b$, and N is increased; by this means the proportion of heat using the air as its medium for conversion into mechanical energy, will be increased, and the resultant efficiency more nearly approach that of a Joule's air engine.

On the other hand, to cause E to approach $E_b$, either $P_1$ is increased or $t_1$ reduced, to diminish the range $t_1 - t_b$. The same effect might be produced by diminishing N, but the limiting case of $E = E_a$ can be reached by making $t_b = t_1$ whatever be the value of N.

In order that the most important quantities determined in the numerical examples, may be still more readily compared with one another, and in each case the effects of the change in the data directly observed with the greatest facility, the following tabular statement was condensed from the more complete one already given.

The calculated quantities which may be selected as being of most importance and interest are:

E, the resultant efficiency of the fluid, (and furnace combined,) or C the consumption of fuel per horse-power per hour, either of which measures the economy of the engine; $P_e$, the mean effective pressure in pounds per square inch, measuring the compactness of the engine for a given power; and $q_e$ the ratio giving the size of the compressing pump cylinder, relatively to that of the main cylinder when both are single or both are double acting.

As before, only the three variable data used in the discussion of the variation of the resultant efficiency, are introduced.

| Ex. No | DATA. | | | RESULTS. | | | |
|---|---|---|---|---|---|---|---|
| | $P_1$ | $t_1$ | N | E | C | $P_e$ | $q_e$ |
| 1 | 32·63 | 450 | 18 | 0·098 | 2·01 | 11·98 | 0·40 |
| 2 | 60· | 450 | 18 | 0·120 | 1·65 | 16·15 | 0·45 |
| 3 | 100· | 450 | 18 | 0·133 | 1·49 | 19·63 | 0·49 |
| 4 | 100· | 600 | 18 | 0·162 | 1·22 | 21·59 | 0·44 |
| 5 | 100· | 450 | 54 | 0·135 | 1·47 | 9·99 | 0·74 |
| 6 | 60· | 600 | 54 | 0·183 | 1·08 | 11·33 | 0.61 |

The values of the data $t_1$ and $P_1$ were determined by the following considerations:

A temperature of 450° Fahr. was thought to be about the limit to which the mixture might be superheated and used with ordinary forms of steam cylinders. Where 600° is reached special arrangements may have to be made for protection against heat, either by jacketing the cylinder with the feed-water, or by adopting some of the plans commonly used in air engines. The temperature of 600° is exceeded in several of the air engines discussed by Rankine, even where the available heat has to be conducted through the cylinder walls. When it is considered that the aero-steam engine can be made to possess all of the advantages in the direct use of the heat of combustion, common to the modern furnace gas engine, with a strict regulation of the upper limit by the water, and freedom of the working mixture from ash particles, it is probable that arrangements may be made to increase $t_1$ considerably beyond 600°.

The pressure $P_1$ is limited by $t_1$, for the reason that if $t_b$ exceed $t_1$ too largely, the heat of compression would exert a destructive action on the pump, unless perhaps, at the expense of a certain loss in efficiency, the pump were jacketed with cold water and its temperature kept down. $P_1$ is also practically determined by the form of boiler, which cannot be divided up into tubes, as is desirable for very high pressures. 100 pounds per square inch above the atmosphere was chosen as a moderate limiting value.

By examining the table, it will be seen that throughout the first three examples $t_1$ and N are maintained the same, and $P_1$ alone is successively increased. In the second example, the increase of $P_1$ from 32·63 to 60 pounds is accompanied by an increase in E, as has already been explained should be the case, as well as a considerable one

in $P_e$ and a slight one in $q_e$. In the third where $P_1$ reaches 100 pounds, the changes observed in the second all become more marked. A comparison of the fourth with the third shows the result of increasing $t_1$ from 450° to 500°; the effects are even more favorable than those caused by the increase in $P_1$, as in addition to an increase in both E and $P_e$, $q_e$ is reduced.

In the fifth, $P_1$ and $t_1$ remaining as in the third, N is increased from 18 to 54 pounds (just three times) but the change is decidedly a disadvantageous one, for while the gain in efficiency is practically insignificant, being less than 2 per cent., $P_e$ is reduced one-half notwithstanding $P_1$ remains at 100 pounds, and $q_e$ is increased in the ratio of about 3 : 2.

The sixth example is taking the direction of Joule's air engine, as the range $t_1$ $t_2$ is so far increased by reducing $P_1$ to 60 pounds with $t_1$ at 600°, while N remains at 54 pounds, that the efficiency of the air is given predominance; as might have been anticipated, $P_e$ is reduced with an increase in $q_e$.

The following are the conclusions arrived at, concerning the most advantageous use of mixed air and steam in the engine under discussion:

1. *When $t_1$ is required to have a moderate value,* so that the effects of heat need not be provided for, *comparatively high values of $P_1$ with the least possible supply of air* N, *are the most advantageous as yielding the highest efficiency consistent with the given temperature, in addition to high mean effective pressures, with moderate size of pump.* The case is well illustrated by the third example. When preparations are made for the use of high temperatures, two additional cases arise.

2. *If at the same time with high efficiency, a high mean effective pressure and small pump are desired to be retained,* $P_1$ *must remain at a high value, and* N *be kept reduced as far as possible.* This case is equivalent to the proceeding one with an elevation of $t_1$, as in example four.

*If the very highest efficiency be required at the expense of an increased bulkiness of the engine,* $P_1$ *may be reduced and* N *increased* as was done in example six.

The value of E in the first two of these three cases, is essentially that of superheated steam, but in the last it approaches that of air as worked in a furnace gas-engine. Even with the use of moderate limiting temperatures as in example three, the calculated value of E largely exceeds that of any steam engine discussed in Rankine's treatise, where the efficiency of the furnace is included. The least theoretical con-

sumption C of coal there given for an engine using steam superheated to 428°, was about 2 pounds, whereas in example three, C calculated upon the same total heat of combustion, i. e. 10,000,000 foot pounds, falls to 1·49 pounds. With the higher value of 600° for $t_1$, in the fourth example, C is reduced to about 1¼ pounds and in the sixth to only 1 1-10 pounds. In this example by slightly further diminishing $P_1$ or increasing N or $t_1$, C might be reduced to one pound or less, and still preserve a mean effective pressure of about 10 pounds, including the resistance of the pump (or more than 20 pounds excluding this resistance;) a combined result that has not been approached in any of the furnace gas-engines so far constructed.

It might be thought essential for the completion of the general problem of this engine, to give a larger number of examples embracing a wider range of data, but upon closer inspection it will be seen that those already discussed cover all necessary ground, especially when it is considered that by the *à priori* reasoning previously given, the results of any changes in the data capable of being largely varied, may be closely anticipated.

In order, however, to impart more concise ideas as to the leading dimensions as well as gross consumption of fuel of aero-steam engines of this class, there may be here introduced with propriety a short application of the results of a few of these examples to as many cases of actual engines, while working according to their data and exerting different given amounts of power.

The best examples to illustrate are probably the third, fourth and sixth, which have just been cited as being typical of the three courses open to advantageous change in the data. Let us thus take the cases of:—

1. A large single cylindered marine engine, to exert 1000 indicated horse-powers, while making 50 revolutions per minute and working according to the data of example three.

2. A locomotive with two cylinders indicating a power of 200 horses and making 150 revolutions while fulfilling the conditions of example four; and

3. A small single-cylindered stationary engine of 10 horse-powers, running with a speed of 80 revolutions, as illustrative of example six.

The quantities to be determined are $V_m$ and $V_p$, the respective volumes in cubic feet of the main and pump cylinders when both are double acting, and $C_l$ and $C_t$ the consumptions of coal by the engine in pounds per hour, and tons per day, respectively.

Denoting by the symbols P and R, the number of horse-powers and rate of revolution per minute of the engine, and referring to the gen-

eral formulæ or examples, for the values of $W_e$, $P_e$, $v_2$, $v_e$, $q_e$ and C, we may directly see that

$$V_m = \frac{33000\ P}{2R \times U_e} \times v_2 = \frac{33000\ P}{2\ R\ P_e} \text{ cubic feet.....} \quad (a)$$

$$V_a = \frac{33000\ P}{2R \times U_e} \times v_e = q_e\ V_m \text{ cubic feet.....} \quad (b)$$

$$C_1 = C \times P \text{ pounds.....} \quad (c)$$

$$C_t = C \times P \times \frac{24}{2240} = \frac{3 \times C \times P}{280} \text{ tons.....} \quad (d)$$

It should be noticed that the first common factor in the second members of both equations (a) and (b,) is the number of pounds of air admitted to the engine for each stroke of the piston.

The table given below embraces the application of these formulæ to the three cases proposed, and includes besides their principal data and direct results of calculation, three additional columns of the equivalent dimensions of the main and pump cylinders, whose diameters $d_m$ and $d_a$, and common stroke s, are expressed to the nearest inch.

TABLE OF APPLICATIONS OF EXAMPLES.

| Case No. | Data of Engine. | | | Data of corres. Examp. | | | Results of Prev. calculations. | | | FINAL RESULTS. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | R | $\frac{s}{d_m}$ | $P_1$ | $t_1$ | N | $P_e$ | $q_e$ | C | $V_m$ | $V_a$ | $d_m$ | $d_a$ | s | $C_1$ | $C_t$ |
| 1 | 1000 | 50 | 1 | 100 | 450 | 18 | 2826 | 0·491 | 1·489 | 116·78 | 57·22 | 64 | 45 | 64 | 1489· | 15·95 |
| 2 | 200 | 150 | 1·5 | 100 | 600 | 18 | 3109 | 0·444 | 1·222 | 3·538 | 1·571 | 17 | 11 | 26 | 244·4 | 2·62 |
| 3 | 10 | 80 | 2 | 60 | 600 | 54 | 1631 | 0·612 | 1·082 | 1·265 | 0·774 | 11 | 9 | 22 | 10·82 | 0·116 |

Both $d_m$ and S were at once determined from $V_m$ by assuming the ratio $\frac{s}{d_m}$, entered among the data in the table, while $d_a$ was computed from $V_a$ after having found S.

In the second case, that of the locomotive engine, the calculated volumes and dimensions apply to one only, of each of the two equal pairs of main and pump cylinders; the gross consumption of coal is that for the whole engine.

Where either the main cylinder or pump is to be single instead of double acting, in order to perform an equal amount of work at the same rate of revolution of the engine, its volumeas obtained from this table must of course be doubled, or if the ratio of the stroke to the diameter remains as before, these latter linear dimensions must be increased in the proportion of $\sqrt{2}$ (= 1·26 nearly) to 1.

Any further comment upon this last set of applications is here unnecessary, as beyond what has already been spoken of in connection with the more general numerical examples, the tabulated results at once explain themselves.

It will be observed by a comparison with the results of actual practice, that in the aero-steam engines here illustrated there are to a great extent combined both the economy in fuel of the furnace gas-air-engine, and the compactness of the ordinary steam engine.

It may also be mentioned that the boilers for such engines admit of being made much smaller than those required for steam engines of the same power, not only because of the absence of waste chimney heat, but also because of the greater facility for imparting heat to the steam by the direct injection of the products of combustion into the water.

The values of the resultant efficiencies of these aero-steam engines that can be practically obtained, will of course be less than those calculated by the formulæ of this article on account of the latter not considering the efficiency of the mechanism, together with such losses as are caused by external radiation of heat, back pressure, incomplete expansion, etc., but in well constructed engines these losses may be so far reduced as not to seriously affect the efficiency, a conclusion that receives confirmation through the nearness of approach of the theoretical results of Professor Rankine's formulæ on steam and air, to those of actual practice.

The large loss arising from condensation in the cylinders of common steam engines, and caused by the readiness with which wet steam imparts its heat to the cylinder walls, is almost wholly prevented in the aero-steam engine. The prevention of such loss has been practically shown in Mr. Warsop's experiments to constitute one of the great advantages in the use of mixed air and steam.

Regarding the condensation that is liable to occur in the latter part of the expansion of the mixture, even when there is no loss of heat whatever by external conduction, it may be further stated that in those cases where this liquefaction takes place at all, because of the initial temperature not being sufficiently high for the ratio of expansion, the liberation of latent heat would theoretically somewhat more than compensate the pressures and volumes of the mixture for the loss in weight of steam, and would so cause the diagrams as calculated upon gaseous expansion to be really a little smaller if anything than the actual ones; the curve of expansion would be affected to a slight extent before the first actual condensation, as steam departs from the laws of a perfect gas sometime before becoming saturated.

It may at first sight appear a little strange that the resultant efficiency is thus directly increased where this condensation occurs, but when it is remembered that the latter is brought about through the increase of the initial pressure of the mixture as compared with its initial temperature, and that such a change is advantageous to the efficiency according to the general remarks previously made upon superheated steam, the fact may be fully accounted for.

The foregoing article embraces a general discussion of the theory of aero-steam engines utilizing the whole products of combustion, as far as it has been at present worked out by the writer, and is published with the desire that its results and conclusions may be the cause of leading to further inquiry into the whole subject, both upon the basis of theory, and if possible of experiment.

CHESTER, PA., Feb. 28th, 1874.

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# THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. RICHARDS, Mechanical Engineer.

[Continued from vol. lxviii., page 122.]

## FORGING.

Workshop processes that can be systematized are the most easy to learn. When a process is reduced to a system it is no longer a subject of special knowledge, but comes within general rules and principles that will enable a learner to use his reasoning powers to a greater extent in mastering it.

To this proposition another may be added that shop processes may be systematized or not, as they consist in duplication, or the performance of operations repeatedly in the same manner. It has been shown in the case of patterns that there could be no fixed system as to their quality or the mode of constructing them, and that patterns and pattern making were matters of special knowledge and skill, and in this respect to be distinguished from other branches of machine construction that could be systematized.

The same rule applies to forging but in a different sense. Unlike pattern making or casting, the general processes in forging are uniform; and still more unlike pattern making or casting, there is a measurable uniformity in the articles produced by forging, at least in machine forging, where bolts, screws and shafts are continually duplicated.

A peculiarity of forging is that it is a kind of hand process where the judgment must continually direct the operations, one blow determining the next, and while the pieces forged may be duplicates there is not uniformity in the manner of producing them. Pieces may be shaped at a white welding heat or at a soft red heat, by one or two strong blows or by a dozen lighter blows, the whole being governed by the circumstances of the work as it progresses.

A smith may not, throughout a whole day, repeat an operation precisely in the same manner, nor can he, at the beginning of an operation, tell the length of time required to perform it, nor even the precise manner in which he will perform the operation. Such conditions are peculiar and apply alone to forging.

I think proper to point out these peculiarities not so much from any importance they may have in themselves, but to suggest critical investigation and to dissipate any preconceived opinions of forging being a simple matter, easy to learn and involving only commonplace operations.

The first impressions that an apprentice forms of the smith's shop as a department of an engineering establishment is that it is a black, sooty, dirty place where a kind of rough unskilled labor is performed, a department that does not demand much of his attention. How far this estimate is wrong will appear in after years when experience has demonstrated the intricacies and difficulties of forging, and when he finds that the skill in this department is harder to obtain and costs more relatively than in any other. Forging as a branch of work requires in fact the highest skill and is one where the operation continually depends upon the judgment of the workman, which neither power nor machines can to any extent supplant.

The soot, hard labor, and heat, deter men from learning to forge, and create a preference for the finishing shop which makes a disproportion between the number of smiths and finishers.

Forging includes the forming and shaping of the malleable parts of machinery, welding or joining pieces together, the preparation of implements for forging and finishing, the tempering of steel tools, and usually case-hardening.

Considered as a process, forging may be said to relate to shaping material by blows or compression when it is rendered malleable by heating.

So far as hand tools and the ordinary hand operations in forging go, there can be nothing said that will be of much use to a learner; in all countries and for centuries past hand implements for forging have remained the same, and if the reader is not familiar with them already he has only to visit any machine forging shop where he will see samples and types of forging tools. There is no use in describing tongs, swages, anvils, punches, and chisels, when there is nothing in their form nor use that is not seen at a glance; but the tools and mechanism for the application of motive power in forging processes deserve careful notice.

Forging machinery consists in rolling mills, trip hammers, steam hammers, drops, and punches, with furnaces, hearths and blast apparatus for heating. The general characteristic of all forging machinery is that of a great force acting throughout a short distance; very few machines, except the largest hammers exceed a half inch of working range and in the average operations not one tenth of an inch.

These conditions of short range and great force are best attained by what may be termed percussion machines, that act by blows instead of slow or gradual pressure, and hence we find that hand and power hammers are the most common tools of the smith's shop.

To exert a powerful force that acts but a short distance, percussive devices are much more effective and simple than those acting by maintained or direct pressure; a hammer head may give a blow equal to a dozen tons by its momentum and absorb the reactive force which is equal to the blow; but if an equal force was to be exerted by screws levers or hydraulic apparatus the apprentice can easily see that an abutment would be required to withstand the reactive force and that such an abutment would require a strength perhaps beyond what ingenuity could devise.

This principle is somewhat obscure and the nature of percussive forces not generally considered; as may be illustrated by investigating the action of a simple hand hammer.

Few people in witnessing the use of a hammer, or in using one themselves, ever think of it as an engine giving out tons of force, concentrating and applying power by functions which if performed by other mechanism would involve trains of gearing, levers or screws; and that such mechanism if employed instead of hammers must lack that

important function of applying force in any direction that the will may direct.

A simple hand hammer is in the abstract one of the most intricate of mechanical agents, that is, its action is more difficult to analyze than that of many complex machines involving trains of mechanism; but our familiarity with hammers makes us overlook this fact and the hammer has even been denied a place among those mechanical contrivances to which there has been applied the mistaken name of 'mechanical powers.'

Let the reader compare a hammer with a wheel and axle, inclined plane, screw or lever, as an agent for concentrating and applying power, noting the principles of its action first and then considering its universal use, and he will conclude that if there is a mechanical device that comprehends distinct principles, that device is the common hammer; it seems indeed to be one of those things provided to meet a human necessity and without which mechanical industry could not be carried on. In the manipulation of nearly every kind of material, the hammer is continually necessary in order to exert a force beyond what the hands may do, unaided by mechanism to multiply their force. A carpenter in driving a spike requires a force of from one to two tons, a blacksmith requires a force of from five pounds to five tons to meet the requirements of his work, a stonemason applies a force of from one hundred to one thousand pounds in driving the edge of his tools; chipping, calking, in fact nearly all mechanical operations consist more or less in blows, and blows are but the application of an accumulated force expended throughout a limited distance.

Considered as a mechanical agent the hammer concentrates the power of the arms and applies it in a manner that meets the requirements of the work. If great force is needed a long swing and slow blows accomplish tons; if but little force is required a short swing and rapid blows will serve; the degree of force being not only continually at control, but the direction at which it is applied also. Other mechanism, if used instead of hammers to perform the same duty, would from its nature require to be a complicated machine and act in but one direction or in one plane.

Another peculiarity of the hammer is that its acting range is continually graduated to the resistance that is opposed; in driving a stake or pile, for example, if it were performed by screws, levers, wedges, or any of the ordinary mechanism for concentrating force, a certain amount

of movement in the motive power could only produce a proportionate movement of the stake or pile, and as it would be impossible to predicate the motive force upon anything so irregular as the resistance of the stake, there would occur a great loss of power and movement; with a hammer, however, the power is all expended in the performance of the work, the working range or the distance through which the hammer moves an object that is struck, is always as the resistance offered.

These remarks upon hammers are not introduced here as a matter of curiosity, nor with any intention of following mechanical principles beyond where they will explain actual manipulation, but as a means of directing attention to percussive agents generally, with which forging processes have an intimate connection.

Machines and tools operating by percussive action although they comprise a numerous class, and are applied in nearly all mechanical operations, have never received the amount of attention in text books that the nature of such machines calls for, nor their extensive use warrants. Such machines have not even been set off as a class and treated of separately, although the distinction is quite clear between machines with percussive action, and those with what may be termed direct action: both in the manner of operating and in the plans of their construction.

There is, of course, no lack of formulæ for determining the measure of force, and for computing the dynamic effect of such machines when acting against a measured or assumed resistance, and so on, but this is not what is meant. There are certain conditions, such as the strains that fall upon supporting frames; the effect produced upon malleable material when struck or pressed, and especially such conditions of work to be performed as will render one or the other of these classes of machines most applicable; these have received but little explanation that is of value to practical men.

To follow this distinction between machines and tools that operate by blows and those with direct action: The first impart force by the momentum of a moving mass that accumulates force throughout a long range, and expends the sum of this accumulated force on the object, the reactive force being absorbed by the inertia of the mass that gave the blow; the machinery required in the operation being only a weight, means to guide or direct it, and some means of connection with the motive power. Take a hand hammer for example, it accumulates and applies the force of the arm and performs all the functions of a

train of mechanism, yet consists only of a small block of metal and handle to guide it.

In machines with direct action such as presses, shears, or rolls, there is required first a train of mechanism of some kind to reduce the motion from the driving power so as to attain force; next this force when exerted must be balanced or resisted by strong framing and powerful shafts; a punching machine for example, must have framing strong enough to resist an upward thrust equal to the force applied to the work, and the frames are always a huge mass, disposed in the most advantageous way to meet and sustain this reactive force, while a 'drop' that is capable of exerting an equal force, aside from the block consists only of a pair of slim guides to direct its course.

Leaving out problems of mechanism, although one of the first importance in forging machines, the adaption of pressing or percussive processes is mainly governed by the size and consequent inertia of the pieces acted upon. In order to produce a proper effect, that is, to start the particles of a piece throughout its whole depth at each blow, a certain proportion between the hammer and the piece must be maintained. For heavy forging this principle has led to the construction of enormous hammers for the performance of such work as no pressing machinery can be made strong enough to perform, although the action of such machinery in other respects would best suit the conditions of the work.

### Trip Hammers.

Trip hammers used in forging, bear a close analogy to, and were, no doubt, first suggested by hand hammers. They are the oldest of power forging machines and extensively used at this time; it will therefore be proper to notice them before steam hammers.

As remarked in the case of other machines that have been treated of, there is no use of describing the mechanism of trip hammers; it is presumed that every engineering apprentice has seen trip hammers, or can do so, and the plan here is to deal with what he can not see, and to learn by casual observation.

One of the peculiarities of trip hammers as machines is the difficulty of connecting them with the driving power,—especially in cases where there are a number of hammers to be driven from one shaft.

The sudden resistance offered to the shafts in starting, the irregular motion that is necessary in most kinds of forging, and the varying amount of power consumed, tend to destroy any connection between

the hammer and the driving power. Rigid connections or metal attachments are inadmissible and slipping belts arranged so as to have the tension varied at will, is the usual and almost the only means of transmitting power to hammers that has been successful.

The sudden and varied resistance to line shafts that drive trip hammers tends to loosen couplings, destroy gearing, and produce strains that are unknown in other cases. Shafting arranged with the usual proportions for transmitting power will soon fail if applied to driving trip hammers.

The motion of trip hammers is a curious problem; a head and die weighing, together with the irons for attaching them, one hundred pounds, will make with a helve eight feet long from two to three hundred blows a minute. This motion exceeds anything that could be attained by a direct reciprocal motion given to the hammer head by a crank and far exceeds any rate of speed that would be assumed from theoretical inferences. The hammer-helve being of wood is elastic and acts like a vibrating spring, its vibrations keeping in unison with the speed of the tripping points. The whole machine in fact must be constructed upon the principle of elasticity throughout and in this regard stands as an exception to almost every other machine known. The framing for supporting the trunnions, which a person without experience would suppose should be made with great rigidity, is found to answer best when composed of timber, and still better when this timber is laid up in a manner that allows it to spring and yield.

Starting from the dies and following through the details of a trip hammer to the driving power, the apprentice will note how many parts contribute to this principle of elasticity: First—the wooden helve, both in front of and behind the trunnion; Next—the trunnion bar which is usually a flat section mounted on pivot points; Third—the elasticity of the framing called the 'husk,' and finally the frictional belt. This gives an idea of the elasticity that is needed in connecting the hammer head with the driving power, a matter that should be borne in mind as it will be again referred to.

Another peculiar feature in trip hammers is the rapidity with which crystallization takes place in the attachments for holding the die blocks to the helves, where no elastic medium can be interposed to break the concussion of the dies; bolts to pass through the helve, although made from the most fibrous Swedish iron, will not last on an average for more than ten days use, and often break in a single day. The safest mode of attaching the die block, and the one most common, is to forge it solid with a band to surround the end of the helve.

At the risk of laying down a proposition not warranted by science, I will mention, in connection with this matter of crystallization, that metal when disposed in the form of a ring, seems to evade the influences that produce crystalline change. A hand hammer for example, may be worn away and remain fibrous, the links of chains and the tires of wagon wheels do not become crystallized, even the tires on locomotive wheels seem to withstand this influence, although the conditions of their use are such as to promote crystallization.

The purpose of introducing the matter here is to direct the attention of the reader to the subject; his own experience can be used in confirming or condemning the accepted theories of crystallization.

Among the exceptions to the ordinary plans of constructing trip-hammers, the most noted perhaps, are those used in the American Armory, at Springfield, U. S., where small hammers with rigid frames and helves, the latter thirty inches long, forged from Lowmoor-iron, are run at a speed of "six hundred blows a minute;" as an example however they prove the necessity for elasticity, in the fact, that the helves and other parts have to be often renewed although the duty performed is of a light character.

## Crank Hammers.

Power hammers operated by crank motion, adapted to the lighter kinds of work, are now commonly met with in the forging shops of Engineering establishments. They are usually of very simple construction, and I will mention only two points in regard to such hammers, that might be overlooked by the apprentice in examining them.

First. The faces of the dies remain parallel, no matter how large the piece may be that is operated upon, while with a trip hammer, the top die moves in an arc described from the trunnions of the helve, and the faces of the dies can only be parallel when in one position, or when operating on pieces of a certain depth. This feature of parallel movement in the dies of crank hammers, is of great importance on some kinds of work, and especially so for machine forgings where the size of the work is continually varied.

The second matter to be noticed in hammers of this class, is the nature of the connection with the driving power, when there will, in all cases, be found the equivalent of the elastic helve, either air cylinders, deflecting springs or other yielding attachments, interposed between the crank and the hammer head, and generally the slipping frictional belt or frictional clutches, as in the case of trip hammers.

The apprentice will no doubt see various modifications of power hammers, constructed upon different plans, but all operating upon the same general principles, and easily analyzed and understood if the principle of their action is studied.

### Steam Hammers.

The direct application of steam to forging-hammers, is beyond question the greatest improvement that has ever been made in forging machinery; not only has it simplified the operations that were carried on before this invention, but it has added many branches and extended the art of forging, to purposes that could never have been attained except by the steam hammer.

The general principles of hammers that have already in part been explained, apply to hammers operated by direct steam, and the apprentice in forming a conception of steam hammers, must not fall into the common error of regarding them as distinct machines, or as operating upon new principles. A steam hammer is nothing more than the common hammer driven by a new medium, a hammer that receives power through the medium of steam instead of by belts, shafts and cranks. The steam hammer supplies other purposes besides transmitting power, and seems to be so perfectly adapted to fill the different conditions of power-hammering, that there seems nothing left to be desired.

Keeping in view what has been said about elastic connections for transmitting motion and power, and elastic cushioning of the vibratory or reciprocating parts, it may be seen that steam as a driving medium for hammers, fills the following conditions:

*First.*—The power is connected to the hammer by means of the least possible mechanism, consisting only of a cylinder, a piston, and slide valve, induction pipe and throttle valve; these few details taking the place of a steam engine, shafts, belts, tension pulleys, cranks and springs, with pulleys, gearing, and all details that are required between the hammer-head and the steam boiler in other cases.

*Second.*—The steam establishes the greatest possible elasticity in the connection between the hammer and power, and at the same time cushions the blow at both the top and bottom of the stroke, or on the top only, as the case may require.

*Third.*—Each blow given is an independent operation, and can be repeated at will, while in other hammers such changes can only be made throughout a series of blows by gradually increasing or diminishing their force.

*Fourth.*—There is no direct connection between the moving parts of the hammer and the framing, except the lateral guides for the hammer-head; the steam being interposed as a cushion in the line of motion, which reduces the required strength and height of the framing to a minimum, and avoids positive strain and concussion.

*Fifth.*—The range and power of the blows as well as their time, are controlled at will; this is the greatest distinction between steam and other hammers, and the particular advantage that has led to their extended use.

*Sixth.*—The power is transmitted to the hammers through a small pipe, that may be carried in any direction and for almost any distance at a very small expense, so that the hammers may be placed in such positions as will best accommodate the work, without reference to shafts or other machinery.

*Seventh.*—There is no waste of power by slipping belts or other frictional contrivances to graduate motion, and finally there is no machinery to be kept in motion when the hammer is not at work.

Keeping these various points in mind, the apprentice will derive both pleasure and advantage from tracing their application in steam hammers that may come under his notice, and the various modifications of the mechanism will only render investigation more interesting.

One thing more must be noticed, a matter of some intricacy, but without which, all that has been explained would fail to give a proper idea of steam hammer action. The valve motions are alluded to.

Steam hammers are divided into two classes, one class having the valves moved by hand, and the other, automatic valve movement.

The action of the automatic hammers are again divided into what is termed the elastic blow, and the dead blow.

In working with elastic blows the steam piston is cushioned at both the up and down stroke, and the action of the hammer corresponds to that of a helve trip hammer; the steam filling the office of a vibrating spring; the hammer gives a quick rebounding blow, the momentum being only in part spent upon the work, and partly arrested by the cushioning of the steam in the bottom of the cylinder under the piston. [To be continued.]

**Immense Standard Pressure Gauge.**—The Government is erecting a standard pressure gauge at the Smithsonian Institution at Washington for the purpose of testing gauges to be used in the experiments on steam boilers. It will have a one inch column of mercury one hundred and fifty feet high, and it will be possible by it to test accurately gauges to a pressure of 800 pounds per square inch.

# Chemistry, Physics, Technology, etc.

## THE EXTERNAL ASPECTS OF THE SUN—ITS PHOTOSPHERE AND SPOTS—ITS CHROMOSPHERE AND CORONA.

By Professor S. P. Langley.

[Continued from vol. lxviii, p. 134.]

How hot is the Sun's surface? It has been estimated at almost every temperature. Sir John Herschel, Father Secchi, and others, place it at, *at least*, 10,000,000 degrees Fahrenheit,* others far less; the most probable estimate I think being that of Sir William Thomson, who considers it to be something near 30 or 40 times as hot as one of our blast furnaces. Whatever it may be, there, literally, the elements melt with fervent heat. Our blast furnaces vaporize a small portion of the iron they render, and the aggregate amount of iron which annually passes out of Pittsburgh chimneys in this condition is reckoned to exceed 5,000 tons. This seems a startlingly large amount, perhaps, but what is it compared with that of that great furnace, the Sun, whose fire-grate area is reckoned not in yards, but in square miles, of which its surface includes 2,300,000,000,000.

In the case of a furnace of known size giving a known amount of heat to each square yard of grate, it is quite possible to calculate accurately how long a given quantity of coal will last. Comparing the Sun to such a furnace, we find we know accurately the area, and adopting a probable value for the rate of emission, it becomes a simple problem in practical engineering to determine how long a given quantity of coal would last if delivered and burned at its surface at a rate of combustion which would just maintain this known heat.

Since the great numbers I have quoted convey by themselves no distinct idea, I have, in the way of illustration, computed how long the entire coal fields of Pennsylvania would keep up the actual solar heat, using the lowest probable estimate of the heat, and the highest estimate of the amount of coal we have under our soil. Let us suppose the actual source of the Sun's heat (whatever that is) to be withdrawn, and that to supply its place we could deliver all the coal which underlies the State, at the solar surface, and burn it with an oxygen blast, so that the Sun should radiate just the heat it does now. When

* Since this lecture was delivered, Father Secchi has published the results of a comparison of the heat of the carbon-points in the electric-lamp, with that of the Sun, giving the latter a very much lower temperature than in his former estimate.

I finished the computation I thought I had perhaps made a mistake, and possibly you may think so, too, but I revised my figures and found them correct. Demonstrably the Pennsylvania coal fields would not last more than a very minute fraction of a second! I must return once more to this subject of the solar heat, but before I do so I wish to speak, though briefly, of the Chromosphere or the red envelope (commonly invisible to the telescope) with the flames which rise from it, and of the Corona.

### THE PROTUBERANCES.

Few indeed, have seen these with the naked eye, as we ordinarily have to travel long distances to enjoy a brief direct sight of them from the track of a total Solar Eclipse. It has been my privilege to thus witness them on two occasions. Nothing can be more impressive than when to the spectacle of the Sun turned to darkness in a cloudless sky is added the sight of these red flames rising around its disc to the height of perhaps 50,000 miles. The spectacle is as brief as it is beautiful, the Government Eclipse Expedition having crossed the ocean in 1870 for an opportunity of observation which it was known in advance would last but two minutes. To all the other elements of grandeur in that scene was added that of the approach of the moon's shadow on the earth. We do not customarily reflect that the moon, which we ordinarily consider in its poetical aspect as it seems slow wandering among the stars—

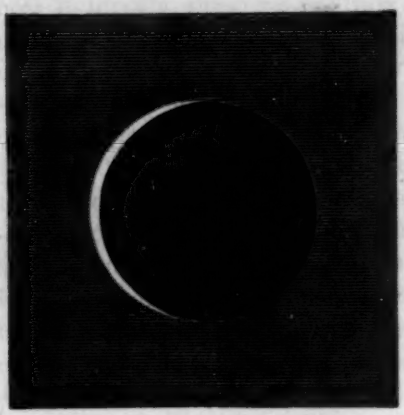

Fig. 3. The Sun just before Totality.

> "Like one who hath been led astray
> Through the heavens' wide, pathless way,"—

is, in fact, an immense projectile hurled through space at the rate of two thousand miles an hour. We do, however, realize this fact when its shadow is thrown upon the ground beside us, and sweeps across the fields where we are, and I think poetry need be no loser by exchanging its fiction for such a reality. On our right, that day, as we faced the fast disappearing Sun at Jeres, lay houses, vineyards, and orange groves; on our left, stretched the far-extended Andalusian plains to a distant range of lofty mountains called the Sierra Morena.

The moon's shadow suddenly appeared in the west, concealing the white house tops and darkening everything like the coming of sudden night, rushed over us and passed us with a speed greater than that of a cannon ball, and, almost instantly blotting out the distant Sierra Morena, seemed to have made but one leap from horizon to horizon. Only when the last ray of light was flitting, the red flames and Corona came out. Fig. 4.

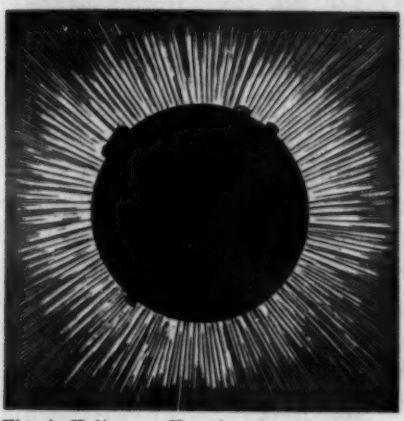

Fig. 4. Eclipse at Totality showing Corona.

I try to simulate the progress of the eclipse by causing a shadow to advance over the screen while moving a plate with my hand, but the halting motion conveys nothing of the impression which reality does when we see the regular and measured advance of the dark body of the moon, extinguishing the light till the last ray is gone—and the Corona appears.

It is impossible to enter on the great subject of spectrum analysis in explaining just how, without an eclipse, the spectroscope enables us to see the protuberances, and this is the less needed as so many here had the advantage of hearing the elucidation of this subject by Professor Barker, in this place. It does so, and so well that on the day before the 1870 eclipse I saw them as clearly through Professor Young's spectroscope, as at the moment of totality. But without intending to speak of the spectroscope further, I may show you a most recent and remarkable improvement in what are known as diffraction spectra, due to Mr. Rutherford, in the shape of these little pieces of glass and speculum metal which I hold in my hand, either of which is equal to a powerful train of prisms.

Fig. 5. Eruption from the Chromosphere.

When with it or the prisms we view the chromosphere, we appear to look through an extremely tall, narrow window, beyond which appears the limb of the Sun with the red chromosphere, and, if we happened to be looking at the part of the edge where an erruption was in progress, we might

witness with it the rising of the rosy flame-clouds which are its products. Fig. 5.

We are supposed to witness in the red clouds you see rising, one of those tremendous eruptions of hydrogen vapor to which the protuberances of the chromosphere are largely due, and as it is important to see that gas can be luminous without burning, I call your attention again to this little illustration of the Sun where the protuberances which now appear are formed of real hydrogen behind the screen. As a fuller illustration of this important point, notice these glass tubes, called Geissler tubes, and which are filled with various colorless gases. When I pass the current from this Ruhmkorff coil through them, they glow with a mild light of various colors and would continue to do so for almost any length of time without waste.

These illustrations may help us to see that the light and heat I have described are not necessarily due to anything "burning up" as in the case of an ordinary fire, or as in the case of this magnesium wire which I light, and which does burn up like a candle.

Magnesium is found very plentifully in the Sun and so are other metals which do not burn so easily but which may all be vaporized by sufficient heat so as to form the metallic clouds I have described. While I prepare to try them in the electric lamp let me direct your attention to this screen, painted, in part, with Thallene, a remarkable substance extracted from the refuse of our Pittsburgh oil stills by Professor Morton, of the Stevens Institute, Hoboken, (and I cannot mention his name without adding that I owe to his kindness not only this illustration, but many other adjuncts to the present lecture). I have alluded to the heat which comes from the Sun, which we all feel and to its light which we all see, but you know there are yet the invisible rays which are commonly supposed (perhaps erroneously,) chiefly to induce chemical action. Thallene has the property of making visible these invisible rays. I light up the screen with the lime light and you see a little difference between one star and another. I throw on the upper rays of the spectrum, from this electric lamp, and the Thallene, by the action called Fluorescence, takes hold of the invisible rays which went across from the lamp and sends them back to us visible in the peculiar greenish light from every alternate star that is painted with it. I return from what is scarcely a digression to show you upon the screen the dazzling image of the carbon points, between which is now playing the intense light and heat of the electric lamp. I now turn out the light and place a piece of iron on a carbon point hollowed into a minute cup.

You see the inverted image of the carbon, with the iron resting on it, apparently upside down, owing to the action of the lens. I bring the points together, the electric flame leaps out again and there you see the image of the boiling iron on the screen. The changed light comes from it. I turn the iron out and put in a piece of pure silver, and the light which you see now comes from that metal as it burns; and, finally, I turn the lamp toward you and put a piece of gold upon the carbon. Splendor which fills our eyes comes from that burning gold, which is already molten and passing away into vapor. I use these illustrations solely in connection with the subject of the metallic vapors to which the photospheric forms are chiefly due; for it is only of the external appearance of the Sun that I have been speaking to-night, and I have tried to read but one chapter in the great volume of our knowledge, leaving the rest of the book unread. But beyond all else, we should find the further study of the Sun interesting in the fact of our personal relations to it. According to a familiar anecdote, George Stephenson, in days preceding those of the present knowledge of such facts, discovered for himself that it was the force of the Sun locked up in the coal, which really drove his engine, and we must remember that this is not only true, but that as regards ourselves, the statement that our own strength comes from the Sun, and that we cannot move except by the force it supplies, is something more than a figure of speech.

Helmholtz and others have shown that we, ourselves, are—physically speaking—exquisite ingenious machines for developing sun-power. All that grows and lives shares this dependence with us. The cars that may have brought us here were drawn by it; the wood of the floor on which our feet rest, was grown by it; the silk we may be wearing was spun by it—its agency was taken as the medium through which were formed the lips that now speak, and the ears that now hear. These are facts—not fictions, not even figurative expressions; but we must still distinguish between what is fact and what is speculation. Science may represent to us—and truly—that it knows nothing of man, but as a combination of certain elements, acted on by certain forces—elements which existed before him from the infinite remoteness of years, before the Sun himself began to shine. Science may say, and truly, that it knows nothing of man's relation to the Sun, which are not those of a thing formed to that which formed it. But while we shall do well to learn from it to make candid confession of ignorance, where ignorance exists, we shall err if we think her ignorance can ever really be our knowledge; and as we stand for a

moment near the boundaries of man's thought, where science has led us only to let go our hand, if it be permitted to express anything which may be only personal, I will do so—not in the words of Helmholtz or Tyndall, but in those coming from another age of thought and adopt, as an expression of my own feeling, the words of Sir Thomas Browne:

"There is surely a piece of Divinity in us—something that was before the elements, and owes no homage to the Sun."

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## RESEARCHES ON THE TEXTURE OF IRON.

By M. JANOYER, C. E., Metallurgist.

(Translated from the *Annales des Mines*, Vol. 5, p. 90, 1874.)

(Continued from Vol. lxviii, p. 139.)

But the converse of the proposition is equally true; that is to say, having given a fibrous iron, it is sufficient to carry it to a high temperature capable of developing its weldability, in order to transform it into a granular iron. Indeed, by bringing one end of a bar of fibrous iron to a welding heat, a granular structure may be developed there; so that in this way we may produce a bar of iron fibrous at one end and granular at the other. This simple experiment, of the highest scientific interest as well as of the widest practical application, gives us the means of producing at will, either granular or fibrous iron according to the needs of the consumer; and this too, without any change in the material at first employed.

In the preceding statements we find an explanation of the reason why railway companies require that their iron rails should be made of granular iron; and why contractors for machinery demand granular iron for those pieces which sustain friction, and which therefore must take a good polish. The reason is that granular iron, being thoroughly welded, is sure not to laminate under the weight of the locomotive or by the friction of rubbing surfaces; as would be the case with fibrous or imperfectly welded iron.

What has now been said applies to the production of crude iron or merchant bar; and it may be asked what becomes of this crude granular or fibrous iron when it is submitted to refining. I answer all the phenomena are reproduced and in precisely the same manner.

If two or more bars of crude granular iron be superposed so as to form a fagot, and this fagot be heated to a welding heat and passed through the series of grooves necessary to form it into a bar, the re-

sult is always granular iron; provided, that, on issuing from the last groove the temperature of the mass is sufficiently high to ensure complete welding. But if, on the other hand, the bar issues from the last groove at a simple red heat, the texture will be fibrous, simply because it is not welded. Rolled too cold, the metal is disintegrated, and the welding destroyed; the particles slide over each other, they are elongated and consequently a fibrous texture is the result.

As a proof of this sliding, a notch is made upon the side of the fagoted bar, half an inch in depth and perpendicular to the end of the bar. The fagot, heated to a welding heat, is then passed through the necessary series of grooves, the notch still remaining normal to the bar. But at the instant when the temperature is no longer sufficiant to maintain the pasty state necessary for welding, the notch changes its form and becomes as it is worked, more and more the shape of a horizontal <.

This simple experiment obviously proves that in the groove, the center or heart of the bar, receives, in passing, only a vertical pressure, and that the two surfaces slide upon it, producing exactly the observed elongation. The proof of this sliding is seen at once on glancing at the bars as they issue from the rolls, and before they are passed to the shears. The center of the extremity which comes through first, always projects beyond both the superior and inferior portions. The reverse is the case with the other end of the bar.

At the moment when the bar, heated to a dull red heat, takes in the groove, the cylindrical surfaces present an obstacle to the passage of the metal, only the center of which passes easily, while the upper and lower portions are obliged to recede before the cylinders which slide upon the bar. If this bar retains at the last groove, a sufficiently high temperature so that there may be no sliding and consequent disintegration of the mass, and so that the welding actually takes place, the bar will be granular in texture. This condition of things is well seen in large bars, which, during the entire process of rolling, have preserved a sufficiently high temperature.

It happens sometimes, however, that in these large bars of granular iron, fibrous iron may be discovered at certain points. The experienced eye at once recognizes the fact that this fibrous texture is only to be found at the junction of the bars which make up the fagot. This fibrous iron, therefore, is due only to the interposition of cinder, a foreign body which prevents the welding. For this reason, many forge masters, in order to ensure the expulsion of this cinder, frequent-

ly subject the fagot to the steam-hammer before rolling it; thus ensuring the removal of the interposed oxides, and securing a perfect weld.

If we cast our eyes over the series of machines employed in the refining of iron, we shall notice that the common practice, after many unfruitful experiments, has returned uniformly to the hammer, under forms more or less various, and has abandoned the squeezer, the rotary shingling machine, and all those other appliances, both simple and ingenious, for effecting a rapid but at the same time a defective shingling. Heavy hammers have alone given uniformly good results.

I mentioned above that hammering in the cold gives to fibrous iron brilliant plane facets, not belonging to the grain inherent in the metal itself. I will attempt now to give my understanding of the manner in which this transformation of fibrous iron in the cold, into granular iron, operates, being produced, as it is, by blows and by successive oft repeated vibrations.

An examination of the wheel tyres of carriages which have run upon a pavement, leaves no doubt of the actual fact. Generally, these tyres are made of fibrous iron. After a period of use more or less great, the iron is found to exhibit large brilliant plane facets. An explanation of this result is easily arrived at by considering what takes place when, by means of a hammer of a certain weight, a bar of iron is struck at any point of its length. The portion immediately between the hammer and the anvil is displaced laterally and is obliged to overcome the resistance of those portions of the bar lying beyond the immediate action of the hammer. The resistance of the two ends acts precisely like two other hammers, and tends to compress the bar in the direction of its length. Hence there is compression of the mass, and hence the grain observed, which always appears, when thus produced, in the form of large brilliant plane facets, entirely distinct from the fine grain originally present in the iron. Precisely the same facets are to be seen on the half section of a bar of fibrous iron which has bent before breaking. The facets are developed by the longitudinal compression of the fibers.

### Proofs drawn from the Study of the Structure of Iron under the Microscope.

From what has now been said, it appears that from a thorough examination into, and a careful comparison of the different modes of manufacturing iron, the result is reached that this metal in a state of

purity and homogeneity, resulting from a good method of fabrication, where the conditions of temperature have been properly observed, is always granular; and, moreover, that this granular texture becomes fibrous whenever the temperature during the process of working, has been allowed to fall so low that a thorough welding of the entire mass cannot take place.

If this be so, the study of iron under the microscope must necessarily reveal a perfect compactness of the metal when in the granular condition, and a corresponding want of homogeneity in the iron when fibrous. This prevision is completely verified by experiment.

This result, however, important as it is, is not the only one obtained by the use of the microscope.* As we shall see further on, this instrument discloses to us in the case of non-welded, that is to say, of fibrous iron made in the puddling furnace, the presence in it of black pulverulent matter (slag) such as I have already mentioned when speaking of the manufacture of iron by the English process. This black substance is closely lodged in the spaces between the fibers, spaces distinctly visible under the microscope.

The study of iron with a Coddington lens for example, magnifying about thirty diameters, has enabled me to establish clearly and incontestably the following facts:—

That iron in a state of purity, is granular.

That granular iron is compact and thoroughly welded.

That fibrous iron is porous, and not perfectly welded.

That mixed granular and fibrous iron is not uniformly welded throughout its mass.

That coke iron (English method) contains foreign matters between its fibers.

That coke iron presents ordinarily a fibrous texture and a structure but slightly homogeneous owing to defective welding.

Let me now give in detail, the observations which have led me to these conclusions. A specimen of iron, made with great care from the best quality of charcoal pig, and therefore being as pure as it is possible to obtain the metal in the present state of the metallurgical art, exhibited, when its fracture was closely examined with the naked eye, a very fine granular structure, showing only a few trifling torn fibers. The finger readily detected upon this sur-

*If any one should desire to repeat and to extend these observations upon iron, they can use, in place of a microscope which is costly and cumbrous to manipulate, simple magnifying glasses of high power, magnifying at least 30 diameters. A lens of this power is quite sufficient.

face, the asperities which have given the name "apiform" to this iron. This name, however, as we shall see, is entirely an improper one, since the fibers have not in fact the crooked form of a fish-hook.

Submitted to examination with the lens, this fractured surface shows a mass of plane facets, entangled in each other without apparent order. At the moment of rupture, certain particles, situated in the plane of fracture and parallel to the acting force, are separated, or in some sense, torn apart from each other, and therefore give, under these particular conditions, flat grains showing brilliant facets. Other particles, on the contrary, being in planes more or less inclined to the direction of the acting force, present themselves to the eye when separated, at a greater or less angle, and produce, as a whole, a texture very fine grained in appearance. In the latter case, the iron has always a greater tenacity, because the particles of the metal, caught between the planes, and crossing in all directions, being more or less inclined to the acting force, are obliged to produce considerable laceration in order to separate from each other. We see, therefore, independently of the granular texture inherent in pure iron, that, of two irons, the one which has the finer texture offers the greater resistance to strain.

Another deduction, not less important (and one which will tend to rectify some very wide-spread errors, too) is that the fineness of grain, taken in absolute sense, is not always due to a more considerable amount of carbon, and consequently, does not always argue a steely tendency. Fineness of grain is a fact entirely independent of carbon. It is sufficient on this point, to call attention to Swedish iron, which, although very steel-like, is not unfrequently very coarsely granular. My own view is, as already stated above, that this fineness of grain only argues an iron of superior quality with reference to its tenacity.

Moreover, in pure iron, speaking metallurgically, independently of its granular texture, the magnifier reveals a compactness and a perfect homogeneity which can arise only from a complete welding.

If, now, a specimen of fibrous iron be submitted to microscopic examination, the results are entirely different. Aside from the very apparent lacerations of fiber, its more or less brilliant aspect, and its greater or less elongation before rupture, the experienced eye is not slow in discovering in it a want of homogeneity which is never shown in granular iron. This want of homogeneity becomes much more

striking when the fibrous iron is examined with a powerful magnifier. There is then to be seen, even in the metallic mass itself, numerous holes and cavities all elongated in the direction of the axis of the bar. These holes are of all forms and of all dimensions. The fractured surface is literally perforated with them; so much so, indeed, that it presents almost the porous aspect of a reed. Perhaps the comparison would be more accurate if we should say that the appearance presented is like that exhibited by a section of a sponge.

Since these cavities keep the different particles of the mass at a distance from each other, and oppose an obstacle to that intimate union of them which constitutes welding, we may even now assert that the microscope establishes the fact of imperfect welding in fibrous iron. Worked, as this iron has been, at too low a temperature, the juxtaposed particles of metal have slid over each other, producing laceration and consequently, the cavities which are observed. It may even happen that a mass of iron which at the outset is thoroughly welded, may become unwelded again by working it at too low a temperature. The result, however, so far as the structure is concerned, is, in both cases, the same.

Iron containing both granular and fibrous metal mixed, can no longer be considered a badly refined iron as Karsten affirms it is; such an iron is simply a metal imperfectly welded.

Beside the influence of the temperature which prevails at the time of working the iron, there is still another and purely mechanical cause which influences its texture. This is the introduction into the metal of some foreign substance, such as unmelted sand, basic slag, etc., which prevents the contact of the molecules. In most cases it is basic slag; and this, being enclosed within the mass, and being but incompletely expelled therefrom, prevents a perfect welding and causes the fibrous structure. In proof of this we see the masters of experimental forges order their workmen to throw highly siliceous sand upon the iron when at a welding heat, in order to favor the expulsion of foreign matters by forming less basic slags, and in this way, to favor the production of a more perfect weld. This slag, so injurious if not removed, is, it seems to me, one of the principal causes which differentiate (the quality of the cast iron being equally good in each case) between charcoal and coke iron. It prevents perfect welding in the case of the latter, and gives to the fiber a dark appearance. Moreover, an examination of the iron with the microscope leaves no doubt upon this question. Fibrous charcoal iron, in which no black places are dis-

cernible with the magnifier, has always a brilliant silvery appearance, and never presents the dull, black, and short fiber characteristic of coke iron.

In order to give an accurate idea of the injurious influence of slag thus interposed throughout the mass of the iron, I will mention here an experiment which seems to be entirely conclusive. It is well known that in the manufacture of charcoal iron by the Franche-Comte method, there is left, at the close of each refining operation, exactly under the opening of the tuyere, a certain quantity of iron (about two kilograms) from the preceding heat; the object being to favor the production of basic slags, the reaction of which upon the foreign metals and the carbon of the pig, is much more energetic than that of neutral slags. (This, in fact, is the scientific explanation of the assertion of the forge-masters, that this iron in burning, gives heat to the slag.) In 1859–60, in order to increase the production of charcoal iron, I ordered about fifteen kilograms of scrap-iron to be added to each charge, believing that it would be thoroughly incorporated with the iron produced from the pig. My surprise was great when, on weighing the product, it was found that the loss in refining was the same which had occurred in previous operations before the addition of the scrap; and that the iron, designed to be drawn into wire, was of a very poor quality. The explanation, however, is simple. The scrap-iron, added too soon, had been entirely oxidized and had formed a highly basic slag, which was not subsequently expelled from the mass. On attempting to draw the iron into wire, this foreign substance abraded seriously the draw-plate and the wire produced broke into short pieces. Returning again to the old method and refining the same pig without the addition of scrap-iron, the quality of the iron became excellent. The experiment was to me, a significant one.

It appears then that the observations which have been made upon iron by means of the microscope, lead to exactly the same conclusions as those obtained by a comparison of the different modes of manufacture of this metal.

## Intimate relation between the physical Properties of Iron and the Welded Condition of the Mass.

### *Density.*

Granular iron being more thoroughly welded than fibrous iron, and consequently more compact and more homogeneous, we should natu-

rally conclude *a priori*, that fibrous iron must have a specific gravity below that of granular iron. This supposition is verified by everything that either theory or practice has to offer upon the question. The learned Upsal professor, Hassenfratz, gives as the density of thoroughly welded granular iron 7·791; and of soft fibrous iron 7·751. Flachat, Barrault, and Petiet give for the former kind of iron, a density of 7·780 and for the latter, of 7·600; a much more considerable difference. In actual practice, we notice that those iron-works which make rails of fibrous iron, can only obtain the required weight per running meter by giving a greater thickness to the transverse section; while those works which produce a granular iron, attain very easily the required weight by following exactly and almost mathematically, the pattern rail furnished by the railway companies. I might cite many other examples upon this point, all proving the greater density of granular iron. But the fact appears to me already demonstrated.

*Hardness.*

The best iron, says Karsten, is that which possesses the greatest hardness; and he places in the front rank as to quality, the very hard iron which is always granular, very pure, and has a silvery fracture. This iron is the type of a thorougly welded metal; it does not contain any slag distributed throughout its mass, nor can any solution of continuity be observed in its texture.

*Tenacity.*

The tenacity of iron is the resistance which the metal opposes to an external force which tends to separate the portions composing its mass. According to the mode of action of the force, we may have:

Resistance to traction.

Resistance to compression.

Resistance to flexure.

Granular iron resists better than any other, both traction and compression. This should necessarily be the case, since it is perfectly welded throughout its mass; and hence the surfaces to be separated are more considerable than those of fibrous iron of equal section.

As to resistance to flexure, however, the reverse is true. Fibrous iron is not welded; an intermolecular approximation is consequently possible before the point of rupture of the bar is reached. This kind

of iron, therefore, opposes a greater resistance to flexure than granular iron, but it has much less elasticity.

### *Malleability.*

Malleability is the property in virtue of which iron is extended under the hammer. This property is especially developed in soft irons, which are irons not welded and always fibrous. Very hard iron, on the other hand, that is to say, welded or granular iron, is hammered out less easily.

### *Ductility.*

This is the property which iron possesses, of being drawn into more or less fine wire without breaking. What is necessary in order that an iron may be ductile? Two conditions: homogeneity, that it may pass the wire-plate, and tenacity, that it may support the traction. Very hard iron, that is to say, our granular welded iron, is the only kind suitable for this purpose. Fibrous, non-welded iron possesses but little homogeneity and could not pass the draw plate; moreover, it would break very often. We see, therefore, that in practice, granular iron is sought after for this purpose and that fibrous, or non-welded iron is rejected. Karsten tells us:* Neutral iron, whatever be its hardness, can be drawn into very fine wire." The granular neutral iron of this siderurgist is evidently our welded iron. If we generalize our observations, we shall notice that those iron-works which make granular iron, i.e., a thoroughly welded and homogeneous iron, obtain a product much more beautiful and free from cracks than that obtained by those establishments which make fibrous iron.

In conclusion, we see again that all the physical properties of iron coincide readily with the view which we have adopted, taken from the standpoint of its texture.

## Influence of certain Metalloids upon the texture of Iron.

### *Sulphur.*

If we glance at what has been written concerning irons containing sulphur and which are consequently hot-short or red-short, we shall find that these irons have generally a fibrous structure, are more or less dark in color, have short fibers, show an absence more or less complete of weldability and, in the cold, offer great resistance to rupture by flexure. In this short statement an entire confirmation of my

* *Manual of Metallurgy*, i. 86.

position is contained. The absence of weldability given by the sulphur, must necessarily produce a fibrous structure. The fibers are black and short because of the diffusion of slag throughout the mass. These irons offer in the cold, great resistance to flexure because of the possible approximation of the molecules before the point of rupture is reached. All these characters belong to irons which are not thoroughly welded.

### *Phosphorus.*

In speaking of the influence of phosphorus upon the structure of iron, I omit from consideration those compounds of phosphorus and iron in which the metalloid is present in sufficient quantity to form true phosphides, since these compounds do not affect the question which I am discussing in this memoir. I shall speak here only of irons containing very small quantities of phosphorus, into which this metalloid enters only in amounts of a few thousandths. Phosphorus under these conditions plays a part diametrically opposite to that of sulphur. Phosphoretted irons weld with facility. Karsten* and all practical metallurgists also tell us of the very considerable weldability of irons which contain phosphorus. Now, since these irons have always a granular structure, we see here additional proof that these granular irons are our thoroughly welded irons.

### Résumé.

Although it would be possible for me to bring forward still other proofs in support of my position, I will stop here, believing that I have sufficiently elucidated the question and have demonstrated that iron possesses only a single texture, and that the granular one; and that this texture depends on one of the most essential properties of iron, its weldability. Every other kind of structure in iron is only a change in the granular texture, resulting from imperfect welding during the process of working the mass.

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## NOTE UPON THE MEMOIR OF M. JANOYER.

By M. L. Gruner.

It is by no means easy to observe the real texture of a more or less malleable metal. In breaking it, certain portions of the bar in which especially it is necessary to study the internal structure, are always

* *Manual of Metallurgy*, i, § 196.